Table 1. Gross beta activity in surface air and precipitation, August 1965

Station location		Air surveillance						Precipitation measurements	
		Number of samples		Gross beta activity, pCi/m³			Last profile in *RHD*	Total depth (mm)	Total deposition (nCi/m³)
		Air	Pptn	Maximum	Minimum	Average [a]			
Ala:	Montgomery	31	5	0.21	<0.10	<0.11	May 65	153	<31
Alaska:	Adak	30	NS	0.16	<0.10	<0.10	Sep 65		
	Anchorage	23	5	0.20	<0.10	<0.11	May 65	25	<5
	Attu Island	9	NS	0.10	<0.10	<0.10	Oct 65		
	Fairbanks	24	4	0.14	<0.10	<0.10	Jun 65	28	<6
	Juneau	15	6	0.29	<0.10	<0.13	Jul 65	55	<11
	Kodiak	8	NS	0.10	<0.10	<0.10	Aug 65		
	Nome	2	NS	0.10	<0.10	<0.10	Dec 65		
	Point Barrow	23	NS	0.10	<0.10	<0.10	Nov 65		
	St. Paul Island	29	NS	0.10	<0.10	<0.10	Mar 65		
Ariz:	Phoenix	30	NS	0.17	<0.10	<0.11	Jul 65		
Ark:	Little Rock	23	3	0.20	<0.10	<0.12	Jun 65	45	<9
Calif:	Berkeley	20	1	0.14	<0.10	<0.10	Aug 65	4	<1
	Los Angeles	31	1	0.16	<0.10	<0.10	Dec 65	1	
C. Z:	Ancon	17	NS	0.10	<0.10	<0.10	Aug 65		
Colo:	Denver	30	NS	0.21	<0.10	<0.13	Aug 65		
Conn:	Hartford	29	11	0.27	<0.10	<0.12	Jul 65	69	<14
Del:	Dover	19	NS	0.23	<0.10	<0.14	May 65		
D. C:	Washington	30	9	0.27	<0.10	<0.13	Nov 65	86	<17
Fla:	Jacksonville	30	16	0.18	<0.10	<0.10	Jun 65	245	<49
	Miami	30	8	0.12	<0.10	<0.10	Jul 65	73	<15
Ga:	Atlanta	5	NS	0.26	0.16	0.20	Apr 65		
Guam:	Agana	31	NS	0.12	<0.10	<0.10	Apr 65		
Hawaii:	Honolulu	31	4	0.14	<0.10	<0.10	Oct 65	32	<6
Idaho:	Boise	27	3	0.20	<0.10	<0.12	Oct 65	16	<3
Ill:	Springfield	28	1	0.31	<0.10	<0.15	Nov 65	5	1
Ind:	Indianapolis	24	12	0.23	<0.10	<0.14	Apr 65	76	<15
Iowa:	Iowa City	28	8	0.22	<0.10	<0.13	Aug 65	107	<22
Kans:	Topeka	31	9	0.21	<0.10	<0.13	May 65	107	<22
Ky:	Frankfort	30	5	0.28	<0.10	<0.15	Nov 65	20	<4
La:	New Orleans	31	15	0.14	<0.10	<0.10	Nov 65	259	<52
Maine:	Augusta	31	11	0.23	<0.10	<0.13	Dec 65	88	<18
	Presque Isle	24	9	0.24	<0.10	<0.12	Aug 65	108	<22
Md:	Baltimore	21	8	0.32	<0.10	<0.16	Jul 65	55	<11
	Rockville Lab	16	NS	0.21	<0.10	<0.13	Oct 65		
Mass:	Lawrence	29	7	0.30	<0.10	<0.16	May 65	52	<11
	Winchester	29	7	0.21	<0.10	<0.12	Sep 65	40	<8
Mich:	Lansing	31	12	0.33	<0.10	<0.16	Oct 65	86	<17
Minn:	Minneapolis	21	10	0.18	<0.10	<0.12	Apr 65	152	<30
Miss:	Jackson	28	6	0.30	<0.10	<0.11	Dec 65	102	<21
Mo:	Jefferson City	31	9	0.22	<0.10	<0.13	Apr 65	129	<26
Mont:	Helena	26	10	0.29	<0.10	<0.14	Sep 65	62	<12
Nebr:	Lincoln	20	4	0.27	<0.10	<0.13	Mar 65	16	<4
Nev:	Las Vegas	30	NS	0.15	<0.10	<0.11	Jun 65		
N. H:	Concord	22	NS	0.31	<0.10	<0.15	Nov 65		
N. J:	Trenton	31	6	0.26	<0.10	<0.13	Dec 65	28	<6
N. Mex:	Santa Fe	29	9	0.13	<0.10	<0.10	Sep 65	50	<10
N. Y:	Albany	22	12	0.25	<0.10	<0.15	Apr 65	73	<15
	Buffalo	29	NS	0.30	<0.10	<0.15	Aug 65		
	New York	30	NS	0.21	<0.10	<0.13	Sep 65		
N. C:	Gastonia	29	10	0.20	<0.10	<0.11	Aug 65	147	<29
N. Dak:	Bismarck	30	6	0.20	<0.10	<0.14	Nov 65	94	<19
Ohio:	Cincinnati	19	NS	0.16	<0.10	<0.10	May 65		
	Columbus	30	10	0.33	<0.10	<0.17	Dec 65	168	<34
	Painesville	24	9	0.29	<0.10	<0.14	Jul 65	53	<11
Okla:	Oklahoma City	25	1	0.18	<0.10	<0.12	Oct 65		
	Ponca City	28	6	0.14	<0.10	<0.10	Jul 65	54	<11
Ore:	Portland	30	5	0.39	<0.10	<0.18	Mar 65	19	<4
Pa:	Harrisburg	30	5	0.20	<0.10	<0.12	Apr 65	75	<15
P. R:	San Juan	26	6	0.10	<0.10	<0.10	Dec 65	136	<27
R. I:	Providence	25	5	0.23	<0.10	<0.13	Oct 65	65	<13
S. C:	Columbia	23	9	0.17	<0.10	<0.11	Sep 65	81	<16
S. Dak:	Pierre	29	NS	0.24	<0.10	<0.14	Jul 65		
Tenn:	Nashville	30	4	0.19	<0.10	<0.12	Oct 65	43	<9
Tex:	Austin	29	2	0.26	<0.10	<0.12	May 65	18	<4
	El Paso	29	4	0.16	<0.10	<0.11	Nov 65	24	<5
Utah:	Salt Lake City	31	6	0.26	<0.10	<0.12	Dec 65	50	<10
Vt:	Barre	29	9	0.23	<0.10	<0.14	Jun 65	97	<20
Va:	Richmond	31	5	0.29	<0.10	<0.13	Jun 65	17	<4
Wash:	Seattle	31	8	0.18	<0.10	<0.10	May 65	39	<8
	Spokane	27	3	0.20	<0.10	<0.12	Apr 65	13	<3
W. Va:	Charleston	30	9	0.20	<0.10	<0.12	Oct 65	53	<11
Wis:	Madison	31	10	0.16	<0.10	<0.11	Jun 65	126	<25
Wyo:	Cheyenne	29	2	0.22	<0.10	<0.12	Jun 65	17	<4
Network summary		1,924	378	0.39	<0.10	<0.12		70	<14

[a] The monthly average is calculated by weighing the individual samples with the length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the < than values represent more than 10 percent of the average, a less-than sign is placed before the average.

NS, no precipitation sample collected.

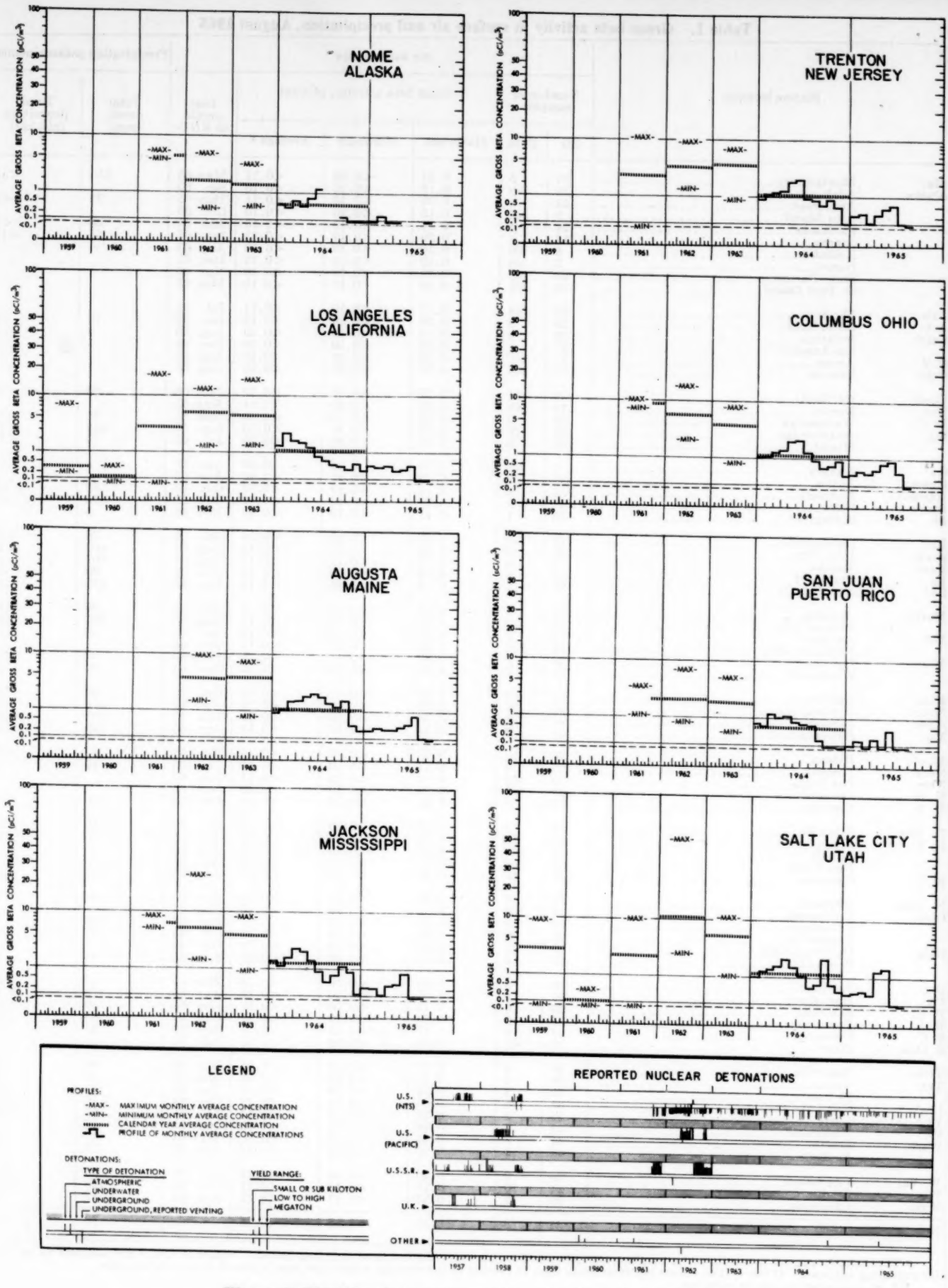

Figure 2. Monthly and yearly profiles of beta activity in air, Radiation Surveillance Network, 1959—August 1965

2. Canadian Air and Precipitation Monitoring [2] August 1965

Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations (figure 3) are located at airports, where the sampling equipment is operated by personnel from the Meteorologic Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*5–10*).

Air sampling procedure and results

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch diameter glass-fiber filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa for analysis.

To determine the beta activity, a 2-inch diameter disk is cut from each filter and counted with a thin-end-window, gas-flow, Geiger-Mueller counter system calibrated with a strontium–90—yttrium–90 standard. Four successive measurements are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for August 1965 are given in table 2.

Precipitation collection and analysis

The amount of radioactive fallout deposited on the ground is determined from measurements on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is 1 month. After transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are added to selected samples according to the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter paper containing insoluble matter together with the polyethylene liner is then ignited and ashed at 450°C. The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infrared lamp, and then

[2] Prepared from September 1965 monthly report "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

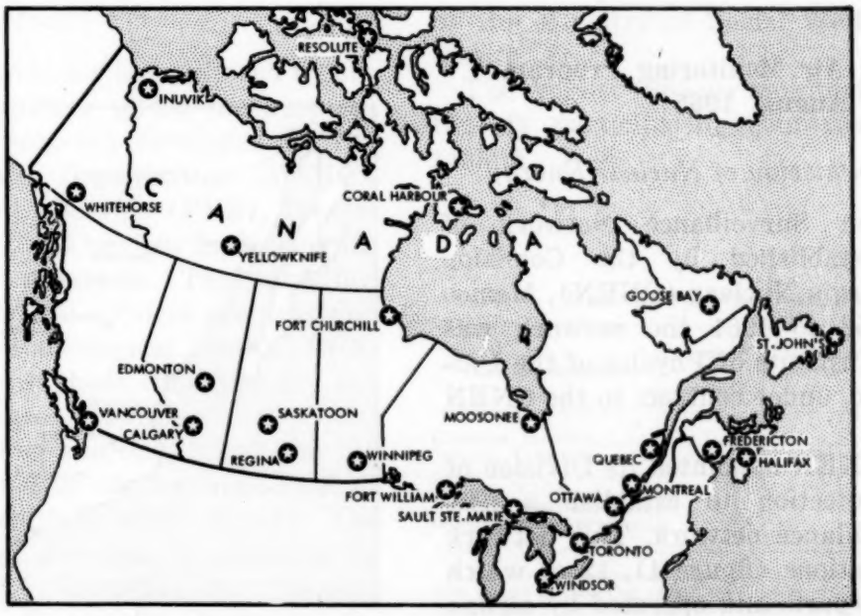

Figure 3. Canadian air and precipitation sampling stations

counted with a thin-end window Geiger-Mueller counter calibrated with a strontium–90—yttrium–90 source. Gross beta activities in precipitation for August 1965 are given in table 2.

Table 2. Canadian gross beta activity in surface air and precipitation, August 1965

Station	Air surveillance (pCi/m³)				Precipitation measurements	
	Number of samples	Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	31	0.3	0.0	0.2	62	4.4
Coral Harbour	29	0.1	0.0	0.0	80	1.7
Edmonton	31	0.2	0.0	0.1	75	4.1
Ft. Churchill	31	0.3	0.0	0.1	128	3.5
Ft. William	31	0.2	0.0	0.1	55	5.5
Fredericton	31	0.3	0.0	0.1	38	4.4
Goose Bay	31	0.2	0.0	0.1	49	4.1
Halifax	31	0.3	0.0	0.1	61	8.0
Inuvik	31	0.3	0.0	0.1	33	3.0
Montreal	31	0.3	0.0	0.1	37	6.0
Moosonee	31	0.2	0.0	0.1	50	5.0
Ottawa	29	0.2	0.0	0.1	65	7.8
Quebec	31	0.2	0.0	0.1	39	7.8
Regina	31	0.3	0.0	0.2	97	2.9
Resolute	31	0.1	0.0	0.0	NS	NS
St. John's, Nfld	28	0.3	0.0	0.1	41	2.2
Saskatoon	31	0.2	0.0	0.1	79	2.3
Sault Ste. Marie	31	0.2	0.0	0.1	69	7.2
Toronto	31	0.4	0.0	0.1	66	4.8
Vancouver	31	0.2	0.0	0.1	65	4.0
Whitehorse	31	0.4	0.0	0.1	93	2.0
Windsor	30	0.4	0.0	0.2	48	3.8
Winnipeg	31	0.2	0.0	0.1	104	3.6
Yellowknife	31	0.2	0.0	0.1	174	2.6
Network summary		0.3	0.0	0.1	70	4.4

NS, no sample.

The monthly precipitation samples represent the total deposition of radioactive materials on the earth's surface. The August 1965 gross beta deposition values are given in table 2. Results of radionuclide analyses of deposition are given in table 3. A review and discussion of fallout levels in Canada during 1964 have been presented by Booth *et al.* (*10*).

Table 3. Radionuclide deposition, nCi/m², in Canadian fallout, August 1965[a]

Station	^{90}Sr (nCi/m²)	^{137}Cs (nCi/m²)
Calgary	0.42	0.63
Coral Harbour	0.17	0.25
Edmonton	0.34	0.63
Ft. Churchill	0.38	0.53
Ft. William	0.55	0.86
Fredericton	0.41	0.68
Goose Bay	0.40	0.66
Halifax	0.54	0.90
Inuvik	0.43	0.43
Montreal	0.49	0.79
Moosonee	0.41	0.62
Ottawa	0.70	1.00
Quebec	0.86	1.29
Regina	0.24	0.42
Resolute	NS	NS
St. John's, Nfld	0.23	0.36
Saskatoon	0.14	0.28
Sault Ste. Marie	0.73	0.52
Toronto	0.44	0.86
Vancouver	0.35	0.53
Whitehorse	0.24	0.36
Windsor	0.34	0.50
Winnipeg	0.30	0.42
Yellowknife	0.29	0.34
Network average	0.41	0.60

[a] Samples from all stations are routinely analyzed for ^{89}Sr, ^{90}Sr, and ^{137}Cs; samples from five selected stations are regularly analyzed for ^{95}Zr and ^{140}Ba. Negligible results are not reported.
NS, no sample.

3. Mexican Air Monitoring Program August 1965

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), Mexico City. From 1952 to 1961 the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN (*11–15*).

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance network. This network consists of 17 stations (figure 4), 12 of which are located at airports and operated by airline personnel. The remaining five stations are

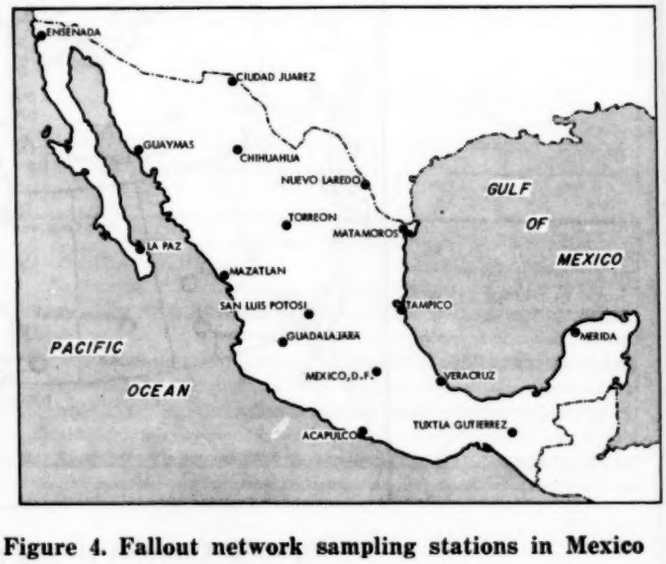

Figure 4. Fallout network sampling stations in Mexico

located at Mexico City, Mérida, Veracruz, San Luis Potosí, and Enseñada. Staff members of the DRP operate the station at Mexico City, while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air for 24 hours a day, 3 to 4 days a week at the rate of approximately 1,200 cubic meters per day, through a high-efficiency, 6- × 8-inch glass-fiber filter, using high volume samplers. After each 24-hour sampling period, the filter is removed and forwarded via airmail to the "Laboratorio de Estudios sobre Contaminación Radiactiva", CNEN, in Mexico City for assay of gross beta activity. A minimum of 3 to 4 days after collection is allowed for decay of natural radon and thoron daughter radioactivity. Data are not extrapolated back to the date of collection.

Results

The maximum, minimum, and average fission product beta concentrations in surface air during August 1965 are presented in table 4.

Table 4. Gross beta activity of airborne particulates, Mexico, August 1965

Station	Number of samples	Gross beta activity, pCi/m³		
		Maximum	Minimum	Average
Acapulco	10	0.2	<0.1	<0.1
Ciudad Juárez	20	0.1	<0.1	<0.1
Chihuahua	20	0.2	<0.1	<0.1
Enseñada	7	<0.1	<0.1	<0.1
Guadalajara	22	0.2	<0.1	<0.1
Guaymas	23	0.1	<0.1	<0.1
La Paz	12	<0.1	<0.1	<0.1
Matamoros	7	<0.1	<0.1	<0.1
Mazatlán	20	0.1	<0.1	<0.1
Mérida	13	<0.1	<0.1	<0.1
México, D.F.	16	0.1	<0.1	<0.1
Nuevo Laredo	16	<0.1	<0.1	<0.1
San Luis Potosí	10	<0.1	<0.1	<0.1
Tampico	18	<0.1	<0.1	<0.1
Torréon	30	0.2	<0.1	<0.1
Tuxtla Gutiérrez	NS			
Veracruz	18	0.1	<0.1	<0.1

NS, no sample collected.

4. Pan American Air Sampling Program August 1965

Pan American Health Organization, and Public Health Service

Gross beta activity in air is monitored by six countries in the Americas under the auspices of a collaborative program developed by the Pan American Health Organization (PAHO) and the Public Health Service (PHS), for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The six air sampling stations included in the Program are operated by the technical staff of the Ministry of Health in each country. The station in Kingston, Jamaica, is operated by the Public General Hospital; in Caracas, Venezuela, by the Venezuelan Institute for Scientific Investigations; in Lima, Peru, by the Institute of Occupational Health; in Santiago, Chile, by the Occupational Health Service; in Trinidad, West Indies, by the University of the West Indies; and in Buenos Aires, Argentina, by the Ministry of Social Welfare and Public Health.

The August 1965 air monitoring results from the six participating countries are given in table 5.

Table 5. Gross beta activity in air, PAHO, August 1965

Sampling stations	Number of samples	Maximum pCi/m³	Minimum pCi/m³	Average* pCi/m³
Kingston, Jamaica	14	0.10	<0.10	<0.10
Caracas, Venezuela	20	0.10	<0.10	<0.10
Lima, Peru	22	0.10	<0.10	<0.10
Santiago, Chile	24	0.10	<0.10	<0.10
Trinidad, West Indies	17	0.10	<0.10	<0.10
Buenos Aires, Argentina	NS			

* The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the values used in the average, a less-than sign is placed in front of the average.

NS, no samples analyzed by laboratory.

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DEPOSITION OF FALLOUT CESIUM-137 AT FORT COLLINS, COLORADO, 1962–1964[1]

Daniel W. Wilson, Gerald M. Ward, and James E. Johnson[2]

Analysis of local precipitation for fallout cesium–137 has been carried out routinely since 1962 in connection with a study of the deposition and transfer of cesium–137 to man via the dairy food chain. The Colorado State University Dairy Farm's system of pastures, feed production fields, and dairy herd has been investigated in order to obtain a model for the passage of cesium–137 from deposition on the fields to the soil, cow's milk, and eventually man, and deposition data presented here have been used already for these purposes (*1*).

The precipitation collectors were three fiberglass funnels, each with a 47.2 ft² catch area and located 6 feet above ground in the fields of the dairy farm. Precipitation including settled dust and soil was passed by gravity from the funnels through ion exchange columns. Cesium–137 was recovered from the ion exchange resins by elution with 0.5 *M* ammonium nitrate (*2*).

This procedure isolated cesium–137 from other interfering fission products, notably zirconium-niobium–95. The residue that collected at the head of the column often contained clay minerals that fixed cesium–137 irreversibly with respect to ammonium nitrate elution. The cesium–137 content of the precipitation sample was determined from the ammonium nitrate eluate and the residue by gamma scintillation spectrometry (*3*).

The annual depositions of fallout cesium–137 in precipitation and as settled dust were 4.14, 16.0, and 15.8 mCi/mi² for 1962 (April through December), 1963, and 1964, respectively. Maximum depositions were coincident with increases in precipitation and ground level air concentrations of cesium–137 that occurred in the late spring and early summer of each year. The daily record of samples, depth of precipitation (inches), and cesium–137 deposition in μCi/mi² are given in tables 1–3. Total integrated depositions on a monthly basis are presented in figure 1.

Table 1. Cesium-137 in precipitation in 1962

Date, 1962	Precipitation (inches)	Cesium-137 (μCi/mi²)
4/26	0.09	ND
4/29	0.42	ND
5/4–7	0.07	243
5/14	0.19	ND
5/16–17	0.29	75
5/17–18	0.31	346
5/20–21	0.12	ND
5/23–25	0.02	46
5/26–27	0.75	445
6/1	0.36	532
6/6	0.33	149
6/16	0.19	199
6/20	0.15	176
6/30	0.50	199
7/8	0.39	512
7/16	0.24	441
7/23	0.34	208
7/26–27	0.40	217
8/1	0.12	30
8/4	0.10	11
8/23	0.11	59
9/8	0.15	42
9/18	0.01	8
9/19–22	0.24	170
10/5–6	1.74	ND
10/15	0.01	ND
11/16–18	0.16	ND
11/18–25	0.17	29
11/29	0.01	ND

ND, nondetectable

Table 2. Cesium-137 in precipitation in 1963

Date, 1963	Precipitation (inches)	Cesium-137 (μCi/mi²)
1/4	0.06	ND
1/11–18	0.17	ND
1/22–2/1	0.15	16
2/2	0.01	ND
2/8–11	0.05	ND
2/16–3/15	1.31	ND
4/2	0.03	ND
4/7	0.01	ND
4/21	0.04	30
4/26	0.28	ND
4/29	0.01	6
5/16	0.03	326
5/19	0.10	248
5/23	0.20	524
6/3	0.17	1,798
6/8	0.28	1,802
6/14	0.23	631
6/15–16	3.04	3,507
6/16	0.03	507
7/4	0.03	346
7/11	0.09	272
7/15	0.03	547
7/16	0.03	280
7/29	0.01	48
8/5	0.13	1,628
8/6	0.18	465
8/9	0.01	118
8/12	0.04	120
8/13	0.09	346
8/15	0.01	70
8/17–18	0.08	295
8/25	0.06	377
8/27	0.26	456
9/10	0.17	294
10/9	0.02	133
10/11	Trace	69
10/20–21	0.37	152
10/21–22	0.16	107
10/26	Trace	16
11/17	0.16	88
11/17–12/31	0.40	345

ND, nondetectable

[1] This work was supported by Atomic Energy Commission Contract AT (11–1)–1171.

[2] Mr. Wilson is a chemist, Dr. Ward is Professor of Animal Science, and Mr. Johnson is a radiation biologist, Colorado State University.

Table 3. Cesium-137 in precipitation in 1964

Date, 1964	Precipitation (inches)	Cesium-137 (μCi/mi²)
1/26–27	0.19	185
2/10	0.24	259
3/12	0.08	260
3/26	0.35	315
4/1	0.05	319
4/3	0.32	277
4/20	0.42	1,232
5/7	0.21	2,172
5/26–27	0.33	1,450
5/28–29	0.30	1,304
5/30–31	0.31	1,356
6/1–2	0.13	359
6/8	0.30	1,166
6/21	0.11	849
6/30	0.06	455
7/23	0.05	585
7/29	0.07	922
8/1–2	0.24	623
8/8	0.04	108
8/13	0.12	358
8/16	0.05	363
9/15	0.21	247
9/18–19	0.18	172
10/10–11	0.15	190
10/11–12	Trace	133
11/14	0.30	127

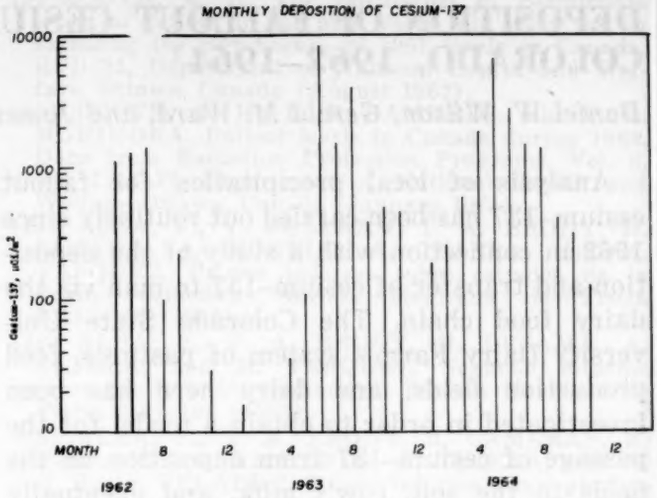

Figure 1. Monthly deposition of cesium–137 at Fort Collins, Colorado, 1962–1964

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(*2*) JOHNSON, J. E., G. M. WARD, D. W. WILSON, and R. D. THOMPSON. Anal Chim Acta, in press.

(*3*) WARD, G. M., J. E. JOHNSON, and D. W. WILSON. Determination of fallout radionuclides in environmental samples by gamma-ray spectrometry. Presented at the symposium on Radioisotope Sample Measurement Techniques in Medicine and Biology, Vienna, May 24–28, 1965.

Section II—Milk and Food

MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to composite and analyze, and samples representative of milk consumption in any area can be readily obtained.

1. Pasteurized Milk Network, August 1965

Division of Radiological Health and Division of Environmental Engineering and Food Protection, Public Health Service

The Public Health Service pasteurized milk surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of this network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this study led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present Pasteurized Milk Network (PMN), which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

Sampling procedure

Samples are collected through the cooperation of State and local milk sanitation authorities. According to established procedures, the sample at each station is composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from 1 day's sales per month and was as representative of the community's supply as possible under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then the sampling frequency has been reduced to once a week.

Samples are preserved with formaldehyde and sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern (NERHL) Radiological Health Laboratories for analysis. Gamma analyses for iodine–131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pCi/liter are immediately telephoned to appropriate State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after weekly samples are received by the laboratories.

Analytical procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintilla-

tion spectrometry.[1] After the weekly samples are gamma-scanned, samples from two consecutive weeks are composited and analyzed radiochemically to determine strontium–89 and strontium–90. With all such measurements, there is an inherent statistical variation. For the low radionuclide levels usually observed in milk and other environmental samples, this variation on a percentage basis is relatively high. It depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclides, and the background count. For milk samples, counting times of 50 minutes for gamma spectrometry and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate analytical errors (including counting error) associated with determinations of radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses.

Table 1. Analytical errors associated with determinations of radionuclide concentrations in milk

Nuclide	Concentration (pCi/liter)	Error [a] (pCi/liter)	Concentration (pCi/liter)	Error [a] (percent of concentration)
Iodine-131	less than 100	10	100 or greater	10
Barium-140	less than 100	10	100 or greater	10
Cesium-137	less than 100	10	100 or greater	10
Strontium-89	less than 50	5	50 or greater	10
Strontium-90	less than 20	2	20 or greater	10

[a] Two standard deviations.

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

The minimum detectable concentration is defined as the measured concentration equal to the two-standard deviation analytical error. Accordingly, the minimum detectable concentrations in units of pCi/liter are: strontium–89, 5; strontium–90, 2; cesium–137, 10; barium–140, 10; and iodine–131, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method, while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium–40 concentrations determined from the gamma spectrum, but are not reported herein.

Data presentation

Table 2 presents summaries of the analyses for August 1965. Radionuclide concentrations below the minimum detectable level have been averaged using one-half the minimum detectable value. However, since October 1963, iodine–131 and barium–140 averages have been calculated on the basis of zero when concentrations below the minimum detectable level were observed. A similar procedure is used for the network average.

Figures 1 and 2 are isogram maps showing the estimated strontium–90 and cesium–137 concentrations in the conterminous United States. The isograms were developed on the basis of extrapolation between the monthly average station values shown.

Figure 1. Strontium–90 concentrations in pasteurized milk, August 1965

Table 2. Average concentrations of stable elements and radionuclides in pasteurized milk for the second quarter 1965 and August 1965 [a]

Sampling locations		Calcium (g/liter)		Strontium-89 (pCi/liter)		Strontium-90 (pCi/liter)		Cesium-137 (pCi/liter)		Iodine-131 (pCi/liter)	
		Second quarter	August	Second quarter	August	Second quarter	August	Second quarter	August	Second quarter	August
Ala:	Montgomery	1.17	1.17	<5	<5	18	14	55	40	0	0
Alaska:	Palmer	1.22	1.19	<5	<5	20	18	65	40	0	0
Ariz:	Phoenix	1.21	1.21	<5	<5	5	4	20	15	0	0
Ark:	Little Rock	1.15	1.12	5	<5	38	26	70	45	10	0
Calif:	Sacramento	1.25	1.20	<5	<5	8	5	35	25	0	0
	San Francisco	1.26	1.19	<5	<5	11	4	35	25	0	0
C. Z:	Cristobal	1.10	1.08	<5	<5	4	4	35	30	0	0
Colo:	Denver	1.33	1.30	<5	<5	19	15	70	35	0	0
Conn:	Hartford	1.11	1.10	<5	<5	15	13	75	50	0	0
Del:	Wilmington	1.14	1.11	<5	<5	19	15	70	40	0	0
D. C:	Washington	1.15	1.13	5	<5	17	13	55	30	10	0
Fla:	Tampa	1.16	1.16	<5	<5	12	12	175	175	0	0
Ga:	Atlanta	1.15	1.14	<5	<5	29	20	85	55	0	0
Hawaii:	Honolulu	1.23	1.15	<5	<5	10	6	55	40	0	0
Idaho:	Idaho Falls	1.27	1.29	<5	<5	20	15	95	45	10	0
Ill:	Chicago	1.13	1.11	<5	<5	17	10	75	35	10	0
Ind:	Indianapolis	1.15	1.11	5	<5	19	12	55	25	10	0
Iowa:	Des Moines	1.26	1.22	10	<5	23	15	55	30	20	0
Kans:	Wichita	1.25	1.21	<5	<5	18	15	50	25	10	0
Ky:	Louisville	1.15	1.10	5	<5	24	18	45	25	10	0
La:	New Orleans	1.20	1.19	5	<5	42	35	80	65	10	0
Maine:	Portland	1.12	1.10	<5	<5	21	21	125	95	0	0
Md:	Baltimore	1.14	1.10	5	<5	19	14	60	35	10	0
Mass:	Boston	1.13	1.11	<5	<5	22	17	125	85	0	0
Mich:	Detroit	1.13	1.09	<5	<5	17	11	75	35	10	0
	Grand Rapids	1.16	1.13	<5	<5	19	13	80	45	10	0
Minn:	Minneapolis	1.29	1.24	10	<5	28	24	90	50	20	0
Miss:	Jackson	1.18	1.18	5	<5	34	25	55	35	0	0
Mo:	Kansas City	1.25	1.14	10	<5	22	18	45	25	30	0
	St. Louis	1.20	1.23	5	<5	19	17	45	25	20	0
Mont:	Helena	1.28	1.25	<5	<5	20	17	95	60	10	0
Nebr:	Omaha	1.19	1.16	5	<5	21	16	50	30	20	0
Nev:	Las Vegas	1.28	1.26	<5	<5	7	5	40	25	10	0
N. H:	Manchester	1.15	1.12	<5	<5	25	20	150	100	0	0
N. J:	Trenton	1.11	1.09	<5	<5	16	14	70	40	0	0
N. Mex:	Albuquerque	1.23	1.27	<5	<5	10	6	35	20	0	0
N. Y:	Buffalo	1.10	1.11	<5	<5	17	10	95	40	0	0
	New York	1.11	1.09	<5	<5	21	16	90	50	0	0
	Syracuse	1.10	1.09	<5	<5	18	11	80	40	0	0
N. C:	Charlotte	1.20	1.13	5	<5	27	24	65	40	0	0
N. Dak:	Minot	1.25	1.31	10	<5	57	29	120	50	10	0
Ohio:	Cincinnati	1.13	1.10	<5	<5	18	13	50	30	10	0
	Cleveland	1.13	1.10	5	<5	20	12	75	35	10	0
Okla:	Oklahoma City	1.12	1.10	5	<5	20	13	45	25	10	0
Ore:	Portland	1.30	1.21	<5	<5	24	14	90	60	0	0
Pa:	Philadelphia	1.13	1.11	<5	<5	19	13	65	35	0	0
	Pittsburgh	1.14	1.11	5	<5	25	19	95	50	10	0
P. R:	San Juan	1.12	1.13	<5	<5	11	9	50	45	0	0
R. I:	Providence	1.12	1.11	<5	<5	20	14	95	65	0	0
S. C:	Charleston	1.16	1.15	<5	<5	27	24	100	70	0	0
S. Dak:	Rapid City	1.05	NA	10	<5	33	16	105	45	10	0
Tenn:	Chattanooga	1.19	1.16	5	<5	30	26	65	40	0	0
	Memphis	1.15	1.13	5	<5	26	19	45	25	10	0
Tex:	Austin	1.12	1.12	<5	<5	8	5	25	15	0	0
	Dallas	1.17	1.11	5	<5	20	11	45	20	0	0
Utah:	Salt Lake City	1.39	1.43	<5	<5	26	9	120	45	10	0
Vt:	Burlington	1.12	1.10	<5	<5	21	15	100	65	0	0
Va:	Norfolk	1.17	1.13	5	<5	21	17	60	40	10	0
Wash:	Seattle	1.27	1.24	<5	<5	25	20	105	75	0	0
	Spokane	1.30	1.33	<5	<5	27	17	90	50	0	0
W. Va:	Charleston	1.12	1.12	10	<5	20	17	40	20	10	0
Wis:	Milwaukee	1.19	1.14	<5	<5	17	10	85	40	10	0
Wyo:	Laramie	1.23	1.18	5	<5	17	15	70	45	10	0
Network average		1.18	1.16	<5	<5	20.7	15.0	72	44	6	0

[a] All station second quarter averages and all station monthly averages for barium-140 were 0.
NA, no analysis.

The distribution of monthly average strontium–90 and cesium–137 concentrations as observed in pasteurized milk for the months March through August 1965 are presented in tables 3 and 4. The average monthly strontium–90 concentrations in pasteurized milk from selected cities in the sampling program are presented in figure 3.

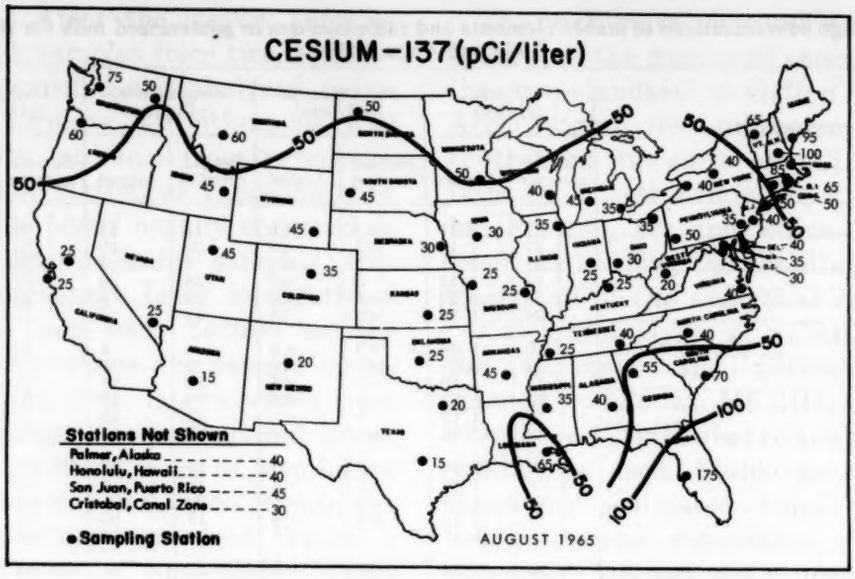

Figure 2. Cesium–137 concentrations in pasteurized milk, August 1965

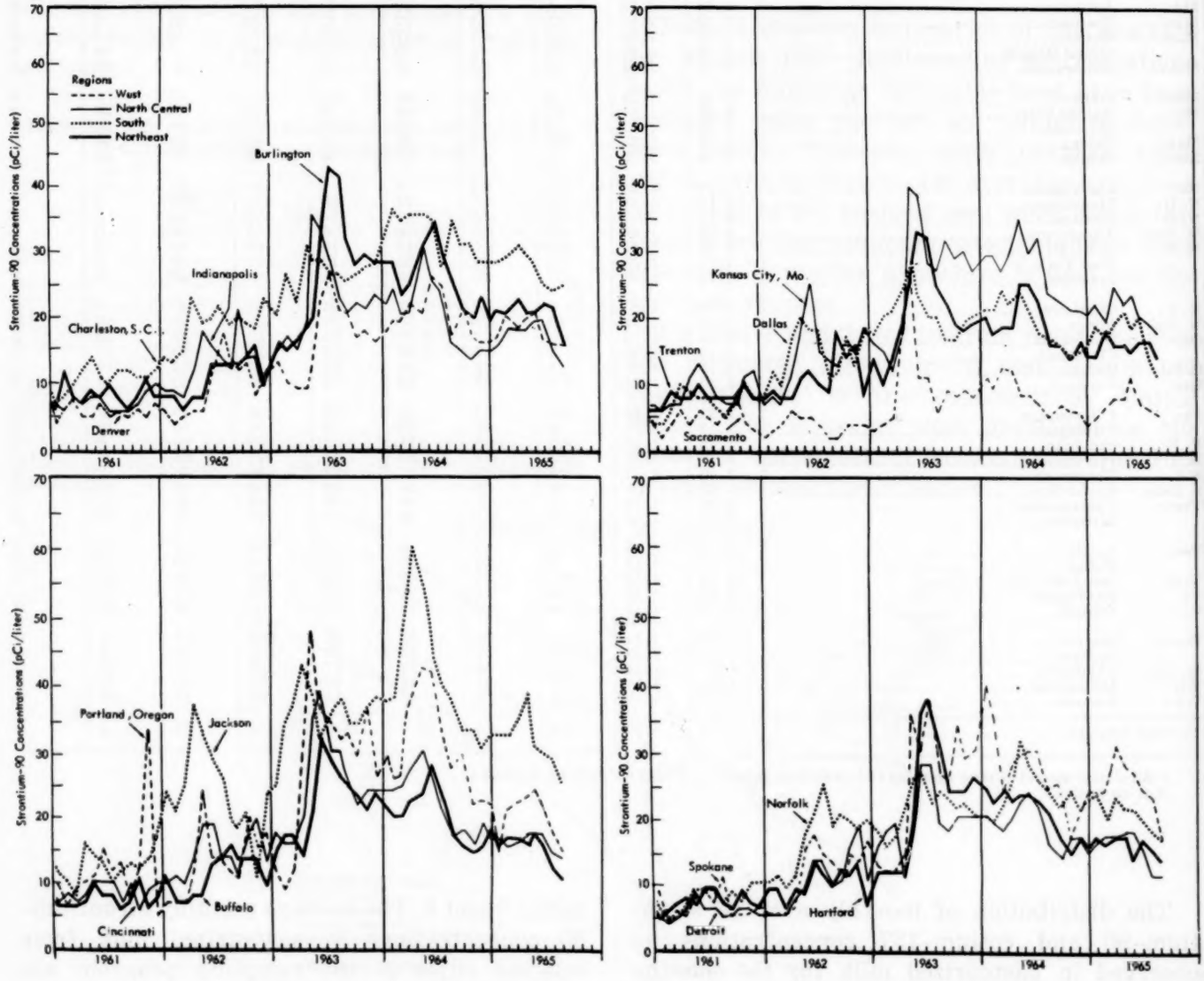

Figure 3. Strontium–90 concentrations in pasteurized milk, 1961—August 1965

Table 3. Frequency distribution, strontium-90 concentrations in milk at PMN stations, March-August 1965 and August 1964

Strontium-90 (pCi/liter)	Number of stations						
	1965						1964
	Mar	Apr	May	June	July	Aug	Aug
Under 10	5	5	4	7	8	10	7
10–19	29	23	26	21	34	41	23
20–29	21	27	25	29	18	11	23
30–39	6	5	5	4	3	1	6
40–49	1	2	2	2	0	0	4
50–59	1	0	0	0	0	0	0
60–69	0	1	1	0	0	0	0
70–79	0	0	0	0	0	0	0

Table 4. Frequency distribution, cesium-137 concentrations in milk at PMN stations, March-August 1965, and August 1964

Cesium-137 (pCi/liter)	Number of stations						
	1965						1964
	Mar	Apr	May	June	July	Aug	Aug
Under 50	9	7	17	19	34	45	6
50–99	36	35	31	38	25	16	30
100–149	16	18	13	5	3	1	19
150–199	2	3	2	1	1	1	6
200–249	0	0	0	0	0	0	1
250–299	0	0	0	0	0	0	1

2. California Milk Network [1] April–June 1965

Bureau of Radiological Health
California State Department of Public Health

Surveillance of specific radionuclides in milk is one phase of California's Department of Public Health program of radiation control. This milk monitoring function has been conducted at eight milksheds since January 1960 by the Department's Bureau of Radiological Health, a constituent of the Division of Environmental Sanitation. Since the addition of the Del Norte and Mendocino milksheds to the program in March 1962, weekly, biweekly, or monthly sampling of pasteurized milk has been conducted at 10 major milksheds (figure 4). The original sampling locations were chosen by the State Department of Agriculture as being representative of milk consumed by a high percentage of the population of the State.

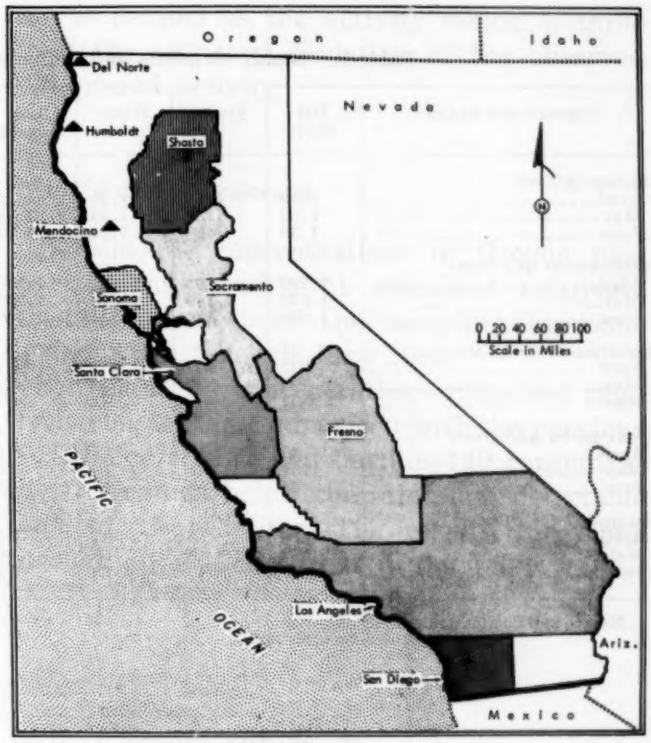

Figure 4. California milksheds

Analytical procedures

After precipitation of the proteins with trichloroacetic acid, strontium is precipitated, scavenged, and beta counted in a low-background counter. After a 2-week ingrowth period, the yttrium–90 is precipitated from the radiostrontium fraction and beta counted. Strontium–90 is determined from the yttrium–90 results; strontium–89 is determined as the difference between total radiostrontium and strontium–90.

Potassium–40, iodine–131, cesium–137 and barium–140 in whole fluid milk are determined by gamma-scintillation spectroscopy using a sodium iodide crystal. A normal counting time of 100 minutes is used. The stable potassium content of milk (g/liter) may be estimated by multiplying the potassium–40 concentration (pCi/liter) by 1.18×10^{-3}. A more complete description of the laboratory equipment and procedures was published earlier (*2*).

[1] This work was summarized under the supervision of Amasa C. Cornish, Senior Health Physicist, Jack L. Brown, Associate Health Physicist, and George Barr, Radiological Health Specialist, Bureau of Radiological Health, California State Department of Public Health.

Results

The monthly calcium and radionuclide concentrations in California pasteurized milk are given in table 5 for the period April to June 1965. As has been previously noted, the Del Norte sample differs significantly from the network average. The appearance of strontium–89 in Shasta and Sonoma counties was not to be expected in light of the previous six months' results. The sudden appearance of this radionuclide, along with increases in strontium–90 and cesium–137, indicates the influx of fresh fission products during this period. A description of the various California milksheds was presented earlier by Heslep and Cornish (*3*).

Network average strontium–90 and cesium–137 concentrations are presented graphically in figure 5. Superimposed upon normal seasonal variations is a decreasing trend since the peak which occurred in the spring of 1963. This peak resulted from 1961 and 1962 atmospheric nuclear testing. This downward trend can be expected to continue with the cessation of atmospheric nuclear testing.

Previous coverage in *Radiological Health Data:*

Period	Issue
July–September 1963	*March 1964*
October–December 1963	*June 1964*
January–March 1964	*September 1964*
April–June 1964	*December 1964*
July–September 1964	*March 1965*
October–December 1964	*June 1965*
January–March 1965	*September 1965*

Table 5. Stable elements and radionuclides in California milk, April–June 1965

Element and month	Del Norte	Fresno	Humboldt	Los Angeles	Mendocino	Sacramento	San Diego	Santa Clara	Shasta	Sonoma	Average
Calcium (g/liter)											
April	1.39	1.19	1.25	1.18	1.12	1.26	1.10	1.11	1.17	1.28	1.21
May	1.59	1.36	1.24	1.23	1.33	1.38	1.29	1.28	1.16	1.42	1.33
June	1.39	1.20	1.26	1.04	1.26	1.16	1.12	1.26	NA	1.23	1.21
Potassium-40 (pCi/liter)											
April	1,200	1,160	1,140	1,190	1,250	1,170	1,180	1,190	1,230	1,210	1,190
May	1,200	1,180	1,170	1,260	1,290	1,240	1,330	1,230	1,160	1,250	1,230
June	1,200	1,160	1,150	1,140	1,260	1,210	1,150	1,290	1,160	1,260	1,200
Strontium-89 (pCi/liter)											
April	ND	ND	ND	ND	ND	ND	ND	NA	4.2	4.7	0.9
May	ND	ND	ND	ND	ND	ND	ND	NA	3.7	ND	0.4
June	ND	ND	ND	ND	ND	ND	ND	NA	NA	1.0	0.4
Strontium-90 (pCi/liter)											
April	40	13	15	4	22	6	4	8	15	14	14
May	51	7	19	4	11	10	5	5	13	13	14
June	33	6	14	3	6	6	3	6	NA	8	9
Cesium-137 (pCi/liter)											
April	116	38	53	34	94	71	23	31	71	79	61
May	110	49	43	28	59	48	24	32	65	32	49
June	57	43	28	14	14	33	20	38	45	29	32

Key to symbols: NA, no analysis performed
ND, below detectable levels.

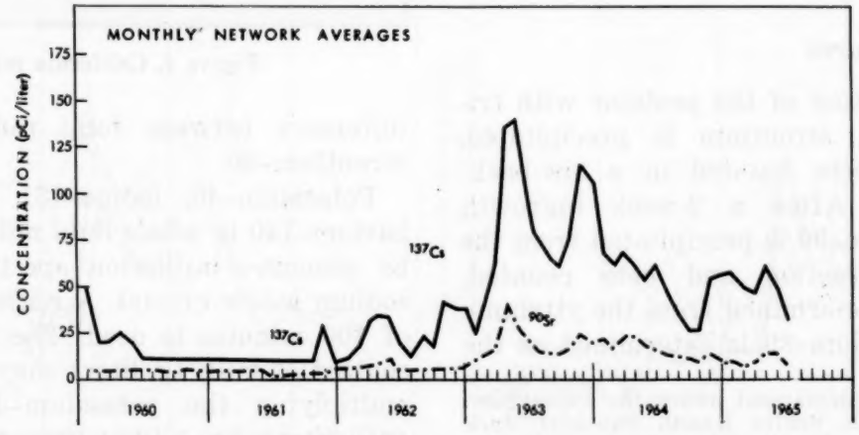

Figure 5. Radionuclides in California pasteurized milk, 1960–June 1965

3. Oregon Milk Network, April–June 1965

Division of Sanitation and Engineering
Oregon State Board of Health

The Oregon State Board of Health has monitored the concentrations of radionuclides in milk throughout Oregon on a continuing basis since the initiation of the milk surveillance program in March 1962. Milk samples are routinely collected at eight major production areas (figure 6), which supply 90 percent of the milk distributed in the State.

Half-gallon samples of pasteurized packaged milk are collected monthly from milk producing plants located in the eight milk producing areas Statewide by Oregon's Department of Agriculture. The Portland milk producing area samples are collected weekly by the city of Portland. The Portland milk district sample is also analyzed as part of the USPHS Pasteurized Milk Network on a weekly basis, with the results serving as a continuing interlaboratory reference. The milk sampling frequency is accelerated to a weekly basis in areas where iodine–131 concentrations exceed 100 pCi/liter, or where cesium–137 concentrations exceed 500 pCi/liter. The strontium–90 analyses are usually performed on a bimonthly schedule, but may be done monthly when significant increases are observed.

[1] This work was summarized under the supervision of George L. Toombs, Chief Radiochemist, Oregon State Board of Health.

Analytical procedures

All milk samples are forwarded to and analyzed by the Oregon State Board of Health Environmental Radiation Laboratory. The concentrations of cesium–137, iodine–131, and barium–140 are determined by gamma spectrometry. The strontium–90 concentrations are determined using a trichloroacetic acid analytical procedure (*4*), with the counting performed by means of a low-background counting system that includes a 2¼-inch detector.

The minimum detectable limits for determining the concentrations of the radionuclides, cesium–137, iodine–131, and barium–140 are 15 pCi/liter; the limit for strontium–90 is 2 pCi/liter. The minimum detectable concentration is defined as the activity which is three times the standard deviation of the observed background activity.

Results and discussion

Cesium–137 concentrations in Oregon pasteurized milk (table 6) remained relatively constant at most of the sampling locations during April through June 1965.

Strontium–90 concentrations remained relatively constant in comparison with the previous period. Iodine–131 and barium–140 concentrations remained below the minimum detectable limit of 15 pCi/liter. The results for April through June 1965 appear in table 6.

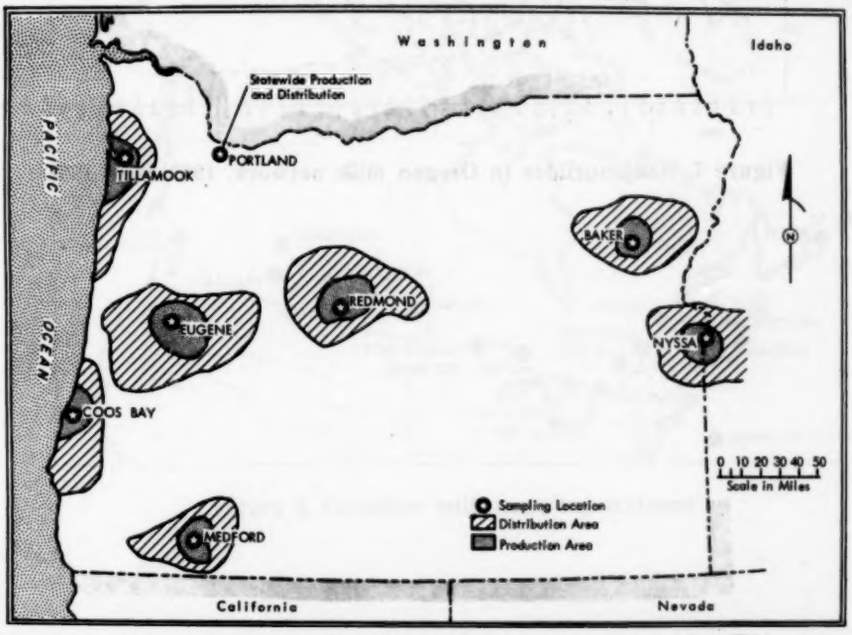

Figure 6. Oregon pasteurized milk network sampling locations showing production and distribution areas

Table 6. Radionuclide concentrations in Oregon milk, April—June 1965

Sampling location	Sampling frequency	Strontium-90, (pCi/liter)			Cesium-137, (pCi/liter)		
		April	May	June	April	May	June
Albany	BM	NA	NS	NA	100	NS	75
Baker	M	NA	17	NA	80	80	80
Coos Bay	M	NA	51	NS	140	140	45
Corvallis	BM	NA	NS	NA	80	NS	50
Eugene	M	NA	14	NA	75	85	55
Medford	M	NA	13	NA	85	80	55
Nyssa	M	NA	15	NA	65	80	80
Portland composite	W	21	27	NA	90	85	90
Portland local	W	NA	25	NA	120	100	90
Redmond	M	NA	13	NA	55	75	70
Tillamook	M	NA	38	NA	120	125	265
Average	—	21	24	—	90	90	90

Key to symbols: BM, sampled bimonthly
M, sampled monthly
W, sampled weekly
NS, no sample collected
NA, no analysis

Additional samples were collected on April 19, 1965, from the Redmond and Baker milk districts following the reported venting of an underground nuclear test on April 14, 1965, at the Nevada Test Site (*5*). No significant changes in the concentrations of the radionuclides were detected in these samples in comparison with previous and prior data at these locations.

General trends for the levels of strontium–90 and cesium–137 can be observed from the concentrations representing the monthly network averages presented graphically in figure 7. The peak concentrations experienced in the spring of 1963 have shown a continual decrease, except for seasonal variations. This general trend can be expected to continue with the prolonged cessation of atmospheric nuclear testing.

The radionuclide concentrations in Oregon milk remain low in comparison to the recommendations of the Federal Radiation Council for remedial action based on health implications.

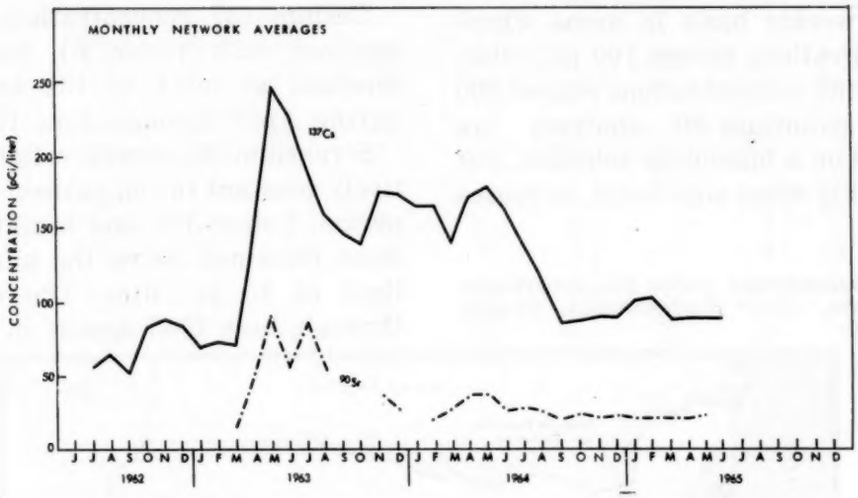
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
250
200
150
100
50
0
137Cs
90Sr
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965

Figure 7. Radionuclides in Oregon milk network, 1962–June 1965

4. Canadian Milk Network [3] August 1965

Radiation Protection Division, Department of National Health and Welfare, Ottawa, Canada

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium–90 in November 1955. At first, analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963, liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and milk sampling locations (figure 8) can be chosen in the same areas as the air and precipitation stations. At present, the analyses include determinations of iodine–131, strontium–89, cesium–37, and strontium–90, as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies, combined into weekly composites, and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine–131. The results of the spot checks for iodine–131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium–90, cesium–137, and stable potassium and calcium.

Analytical methods

Since it represents a more sensitive method, radiochemistry, rather than gamma spectrometry, is used to determine iodine–131 (*6*). For the analysis of radiostrontium, carrier strontium is added to a 1-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet and evaporated under infrared lamps. The residue is ashed in a muffle furnace at 450°C. and dissolved in dilute nitric acid; strontium is separated by fuming nitric acid precipitation. The combined strontium–89 and strontium–90 are determined by counting in a low-background beta counter.

[3] Prepared from information and data in the September 1965 monthly report "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

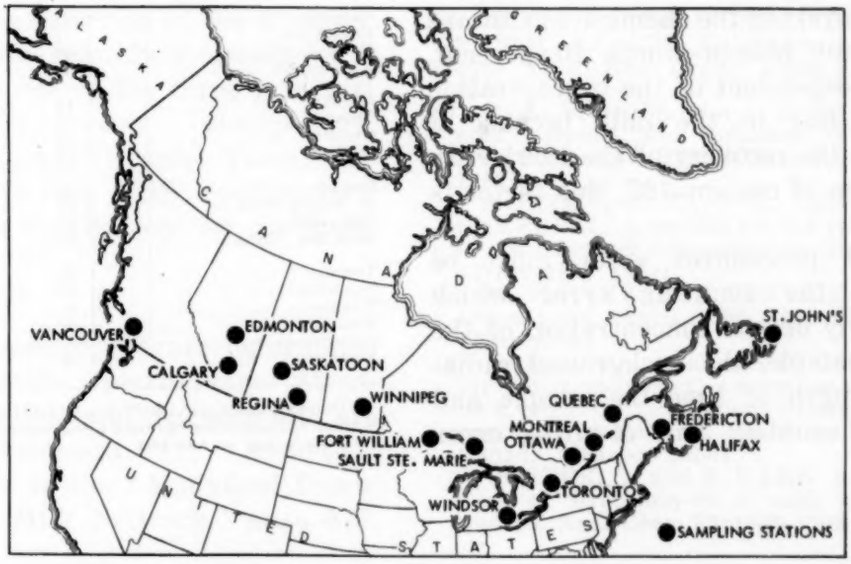

Figure 8. Canadian milk sampling stations

Strontium–90 is determined separately by extracting and counting its yttrium–90 daughter, while strontium–89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium–137 is determined by gamma spectrometry using a scintillation crystal and a multi-channel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5- × 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum is then recorded. Estimates are made of the potassium–40 and cesium–137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method the potassium–40 concentration is determined and the Compton contribution of this radionuclide to the cesium–137 photopeak is subtracted to obtain the cesium–137 concentration. The stable potassium content is estimated from the potassium–40 concentration.

Sources of error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radionuclide in the milk because it depends only on the recovery of the carrier. In the determination of cesium–137, this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated methematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 7.

Table 7. Total error for various radionuclide concentrations in milk [a]

Nuclide	Error for 10 pCi/liter	Error for 50 pCi/liter	Error for 100 pCi/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±60%	±20%	±10%

[a] All errors are 2σ values, representing 95 percent confidence levels.

Results

Table 8 presents monthly averages of strontium–90, cesium–137, and stable calcium and potassium in Canadian whole milk. Spot checks for iodine–131 and strontium–89 indicate that all samples had insignificant levels of these radionuclides.

The results show that radionuclide concentrations in Canadian whole milk remained well below the levels permissible on health grounds.

Table 8. Radionuclides in Canadian whole milk, August 1965 [a]

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.17	1.5	19.5	50
Edmonton	1.11	1.7	20.2	96
Ft. William	1.00	1.6	25.7	115
Fredericton	1.00	1.6	28.9	152
Halifax	1.11	1.5	27.7	108
Montreal	1.04	1.6	18.9	50
Ottawa	1.13	1.8	11.7	34
Quebec	1.07	1.7	16.7	110
Regina	1.05	1.5	17.1	58
St. John's, Nfld	1.04	1.4	51.2	244
Saskatoon	1.11	1.4	34.8	59
Sault Ste. Marie	1.08	1.8	22.8	105
Toronto	1.05	1.6	7.0	52
Vancouver	1.15	[b]	17.4	[b]
Windsor	1.11	1.6	6.9	19
Winnipeg	1.00	1.8	17.7	72
Average	1.08	1.6	21.6	88

[a] Due to insignificant levels of iodine-131 and strontium-89, the reporting of these radionuclides has been discontinued.
[b] Sample lost in analysis.

5. Pan American Milk Sampling Program August 1965

Pan American Health Organization, and Public Health Service

In accordance with a joint agreement, the PAHO (Pan American Health Organization) and the PHS (Public Health Service) developed a collaborative program for furnishing assistance to health authorities in the Americas engaged in developing programs in radiological health.

Under this agreement, the PHS Division of Radiological Health furnishes to PAHO, on a loan basis, limited quantities of essential items of equipment and the requisite laboratory services to establish a surveillance program.

Sampling procedure

Initially, air sampling stations were established in Chile, Jamaica, Peru, and Venezuela. In August 1963, this was expanded to include a milk sampling station in Caracas, Venezuela. Between April 1964 and August 1964, milk stations were added in Jamaica at Kingston, Montego Bay, and Mandeville. Sampling varies according to local procedures.

Under the direction of the Venezuelan Institute for Scientific Investigation, weekly samples are collected, preserved with formaldehyde, and composited monthly.

Jamaica, under the direction of the Ministry of Health, collects one monthly composite on a rotating basis from one of the three principal milk areas; Montego Bay (Montpelier), Mandeville, and Kingston (Spanish Town). All samples are sent to the PHS Southeastern Radiological Health Laboratory for analyses.

Analytical procedures

Iodine–131 and cesium–137 are determined by gamma scintillation spectrometry. Strontium–89, strontium–90, and barium–140 are determined radiochemically (*7*). Analytical errors are discussed in the "Analytical Procedures, Pasteurized Milk Network," page 677.

Data presentation

Table 9 presents stable calcium and potassium, strontium–89, strontium–90, and cesium–137 monthly average concentrations. The monthly average of iodine–131 and barium–140 concentrations in milk were less than 10 pCi/liter.

For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico, are presented.

Table 9. Stable element and radionuclide concentrations in PAHO milk, August 1965

Sampling station	Calcium (g/liter)	Potassium (g/liter)	Strontium-89 (pCi/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Canal Zone:					
Cristobal	1.08	1.4	<5	4	30
Jamaica:					
Kingston	NS				
Mandeville	NS				
Montego Bay	1.20	1.3	<5	17	390
Puerto Rico:					
San Juan	1.13	1.6	<5	9	45
Venezuela:					
Caracas	1.19	1.5	<5	3	15

NS, no sample.

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APPLICATION OF RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK TO INTAKE GUIDES, SEPTEMBER 1964—AUGUST 1965

Division of Radiological Health, Public Health Service

The concentrations of specific radionuclides in milk analyzed as part of the Pasteurized Milk Network (PMN) are reported on a monthly basis in *RHD*. In terms of radiological health surveillance activities, an important aspect of these data is the estimation of resultant radiation dose to population groups.

Approximate relationships between certain radionuclide intakes and dose have been applied to the formulation of daily intake guides (*1*) and permissible concentrations in selected environmental media (*2*). Although these guides are not themselves directly applicable to worldwide fallout, a comparison with environmental contamination levels does yield a measure of population dosage. In general, intake-dose and dose-biological effect relationships used in formulating the guides cited are based on continuous intake over an entire lifetime. However, for general surveillance purposes, yearly average intakes, used with discretion, may be compared directly with the levels adopted as lifetime intake guides. Thus, the radionuclide concentrations in milk, averaged over a year's time, together with milk consumption data, might be used in conjunction with the references cited above to approximate the radiation dose to a specific population group from a specific radionuclide. Table 1 presents annual averages of radionuclide concentrations in milk sampled by the PMN. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U.S. population (*3–4*).

Total dietary intake is of prime interest, and since the intake via milk consumption constitutes only a portion of the total radionuclide intake, the relationship of milk intake to total dietary intake is of importance in evaluating milk surveillance data. The Federal Radiation Council (*5*) notes: "A number of studies have shown that conservative estimates of the strontium–90 to calcium ratio in the total diet may be made by multiplying the ratio of strontium–90 to calcium in milk in a particular locality by 1.5."[1] Thus, a rough index of the total dietary intake of strontium–90 on an annual basis may be made from PMN annual averages by using this factor and the assumptions of approximately 1.2 grams of calcium per liter in PMN samples and a 1.0 gram daily intake of calcium.

In the case of iodine–131, milk can be considered the major source because of the rapid distribution and consumption of fresh milk. With most other foods, normal processing and distribution allows time for this short-lived nuclide to decay to insignificant levels.

The situation with respect to strontium–89 is more complicated. Its half-life of some 50 days makes it difficult to estimate the relative contribution made by sources other than milk to the total dietary intake.

The relative contribution of milk to the total dietary intake of cesium–137 is not well defined and depends principally on the amount of freshly deposited cesium–137 on products used for human and animal consumption, and the progress of cesium–137 through the food chain.

The data in table 1 are calculated as follows: results from all samples collected in each week (Sunday through Saturday) are averaged, and the averages for all weeks terminating in each of 12 consecutive months are averaged to obtain the annual average.[2] To obtain the annual average daily intake (pCi/day) of radio-

[1] This ratio may vary from 1 to 2, depending on changes in rate of fallout deposition and relative consumption of nonmilk products whose contamination reflects temporal and local deposition patterns (*6*).

[2] Beginning with the October 1963 data, iodine–131 values of <10 pCi/liter are considered to be zero for averaging purposes; previously, 5 pCi/liter was used for calculating the averages.

Table 1. Average radionuclide concentrations in milk (pCi/liter) for the 12-month periods,[a] August 1964–July 1965 and September 1964–August 1965

Sampling locations		Strontium-89		Strontium-90		Iodine-131		Cesium-137	
		Aug 1964–July 1965	Sept 1964–Aug 1965	Aug 1964–July 1965	Sept 1964–Aug 1965	Aug 1964–July 1965	Sept 1964–Aug 1965	Aug 1964–July 1965	Sept 1964–Aug 1965
Ala:	Montgomery	3	3	19	18	0	0	53	51
Alaska:	Palmer	3	3	17	18	1	1	73	67
Ariz:	Phoenix	3	3	5	5	0	0	24	23
Ark:	Little Rock	5	5	35	34	2	2	68	65
Calif:	Sacramento	3	3	7	7	1	1	30	30
	San Francisco	3	3	8	8	0	0	31	30
C. Z:	Cristobal	3	3	5	5	0	0	42	40
Colo:	Denver	3	3	18	18	1	1	71	65
Conn:	Hartford	3	3	17	17	0	0	85	80
Del:	Wilmington	3	3	18	18	2	2	71	67
D. C:	Washington	3	3	17	16	2	2	53	51
Fla:	Tampa	3	3	13	13	0	0	194	187
Ga:	Atlanta	3	3	26	25	1	1	86	82
Hawaii:	Honolulu	3	3	11	10	0	0	64	61
Idaho:	Idaho Falls	3	3	20	20	2	2	93	88
Ill:	Chicago	3	3	16	15	2	2	75	71
Ind:	Indianapolis	3	3	16	16	4	4	60	56
Iowa:	Des Moines	4	5	22	21	6	6	56	53
Kans:	Wichita	3	3	18	18	2	2	46	44
Ky:	Louisville	4	4	23	22	2	2	47	45
La:	New Orleans	5	5	41	40	2	2	83	78
Maine:	Portland	3	3	23	23	2	2	137	130
Md:	Baltimore	3	3	18	18	2	2	58	56
Mass:	Boston	3	3	23	22	0	0	133	123
Mich:	Detroit	3	3	15	15	3	3	75	70
	Grand Rapids	3	3	18	18	2	2	84	80
Minn:	Minneapolis	7	7	26	26	5	6	86	81
Miss:	Jackson	3	3	33	32	1	1	60	55
Mo:	Kansas City	5	5	22	21	8	8	47	45
	St. Louis	4	4	17	17	4	4	45	42
Mont:	Helena	3	3	18	18	3	3	92	88
Nebr:	Omaha	3	3	20	19	4	4	56	52
Nev:	Las Vegas	3	3	7	7	2	2	42	40
N. H:	Manchester	3	3	25	24	1	1	154	145
N. J:	Trenton	3	3	16	15	1	1	72	68
N. Mex:	Albuquerque	2	2	9	9	1	1	39	37
N. Y:	Buffalo	3	3	16	15	0	0	93	88
	New York	3	3	20	19	2	2	95	89
	Syracuse	3	3	16	16	1	1	82	79
N. C:	Charlotte	3	3	30	29	1	1	69	63
N. Dak:	Minot	7	6	47	46	2	2	115	109
Ohio:	Cincinnati	3	3	17	17	2	2	55	53
	Cleveland	4	4	18	17	2	2	76	72
Okla:	Oklahoma City	4	5	19	18	2	2	46	44
Ore:	Portland	3	3	23	21	0	0	98	88
Pa:	Philadelphia	3	3	17	16	0	0	68	65
	Pittsburgh	4	4	24	23	2	2	94	88
P. R:	San Juan	3	3	11	11	1	1	53	51
R. I:	Providence	3	3	19	19	0	0	102	95
S. C:	Charleston	3	3	29	28	1	1	95	90
S. Dak:	Rapid City	7	7	30	28	4	4	110	105
Tenn:	Chattanooga	4	4	32	31	1	1	67	62
	Memphis	4	4	25	24	2	2	44	41
Tex:	Austin	3	3	8	7	2	2	29	28
	Dallas	3	3	17	17	1	1	40	38
Utah:	Salt Lake City	3	3	22	21	2	2	117	106
Vt:	Burlington	3	3	21	20	2	2	111	103
Va:	Norfolk	4	4	16	15	3	3	60	58
Wash:	Seattle	3	3	23	22	0	0	104	95
	Spokane	3	3	25	24	0	0	97	91
W. Va:	Charleston	4	4	19	18	2	2	43	40
Wis:	Milwaukee	3	3	14	14	3	3	85	81
Wyo:	Laramie	3	3	15	15	2	2	71	65
Network average		3	3	19.6	19.0	2	2	75	70

[a] Annual averages for barium-140 at each station were <2 pCi/liter

nuclides from milk, the annual average concentration values (pCi/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk.

Monthly variations of radionuclide concentrations in milk are influenced by a number of combined causes such as meteorologic conditions and dairying practices, apart from considerations of original sources of radionuclides. The moving yearly average (table 1) obtained by updating the previous 12-month average by 1 month, shows variations averaged over the year and tends to minimize purely seasonal variations.

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SUMMARY OF RESULTS OF INSTITUTIONAL TOTAL DIET SAMPLING NETWORK, 1961–1964

R. D. Grundy[1], *C. Calvert*[2], *A. G. Berger*[3]

The results of monthly radionuclide analyses of Institutional Diet Samples are periodically reported in *Radiological Health Data*. A discussion of the network's objectives and sample collection and analytical procedures appears elsewhere (*1*, *2*).

Approximately 21 institutions have cooperated in the study from 1961 through 1964. Each monthly sample consists of 21 meals plus snacks, collected during one week in the month. Drinking water is not included in the sample. Under the sampling protocol, a different individual was chosen each day of the sampling week and his diet for that day was duplicated for inclusion in the sample. The resultant weekly sample consists of the combined daily meals of seven individuals. In some cases less than 21 meals were eaten during the sampling period. Where the missing meals were not eaten at the institution or elsewhere the sample was assumed to be complete. Where missing meals were eaten elsewhere, the daily intakes were adjusted to account for unsampled meals.

Where it was necessary to discontinue sample collection at an institution in a particular city, sample collection was later begun at another institution in the same city. It was not possible to collect representative samples from children of all ages and both sexes each month at an institution. Variations in types and quantities of food consumed by individuals or groups made it necessary to consider types and quantities of food consumed in terms of mean values and deviations.

The primary purpose of the program is to measure the radionuclide concentrations in the diet and variations in radionuclide intake with time. Analyses were made for strontium–89, strontium–90, radium–226 (or total radium), cesium–137, barium–140, and iodine–131. To assist in the evaluation of these results, average daily intakes were determined for each sampling period, along with calcium, phosphorus and potassium concentrations.

The population group sampled consisted of children in boarding schools and institutions. As is customary in such establishments, efforts are made to supply an adequate nutritive diet based upon standard portions. In such circumstances (standard portions), the sampling of seven daily intakes at a given institution for a given month may be assumed as reasonably representative of the institution. Since the institutions have been selected to arbitrarily represent major metropolitan areas, it is possible to discuss intake values only on a nationwide basis in terms of distributions and ranges. Future extrapolation to children in the general population will be investigated when additional data regarding individual food consumption (based on probability sampling) become available. This summary is concerned with the trends in radionuclide intakes as reflected in institutional diet program yearly averages at each station, and network monthly averages, maxima, and minima, from 1961 through 1964.

Intakes

Table 1 presents the annual averages of monthly diet and nuclide intakes for each of 21 institutions.[4] These results are based on the 21 institutions which have provided monthly samples since 1961.

[1] Chief, Environmental Data Unit, Data Collation and Analysis Section, Radiation Surveillance Center, DRH, PHS, Washington, D.C.
[2] Project Officer, Technical Operations Branch, DRH.
[3] Chief, Demographic and Sampling Quality Control Staff, Radiation Surveillance Center, DRH.

[4] Based upon monthly values previously published in *Radiological Health Data*.

Table 1. Average annual institutional

	Year	Alaska, Palmer	California, Los Angeles	Colorado, Denver	Florida, Tampa	Georgia, Atlanta	Hawaii, Honolulu	Illinois, Chicago	Louisiana, New Orleans	Massachusetts, Boston	Minnesota, Minneapolis	Missouri, St. Louis
Number of samples	1961	3	11	12	2	10	2	3	—	2	—	9
	1962	12	7	11	9	12	11	6	12	12	12	6
	1963	12	9	11	12	12	11	6	12	12	12	9
	1964	12	9	12	12	10	10	12	12	12	9	12
Total weight (kg/day)	1961	1.91	1.60	2.06	1.84	1.56	2.11	1.63	—	2.16	—	2.37
	1962	1.48	1.49	2.02	1.68	1.63	1.93	1.54	2.22	1.90	1.61	3.00
	1963	1.51	1.83	2.19	1.97	1.63	1.74	1.64	2.28	1.74	1.74	2.53
	1964	1.50	1.79	2.42	2.16	2.01	1.71	1.57	2.58	1.69	1.74	2.43
Calcium (g/day)	1961	0.7	1.0	1.7	1.2	0.8	0.6	1.0	—	1.1	—	1.2
	1962	1.0	0.8	1.6	0.9	1.4	0.8	0.9	1.4	1.3	0.9	1.9
	1963	0.8	1.0	1.3	1.2	0.8	0.7	1.1	1.5	1.3	0.7	1.6
	1964	0.8	1.2	1.5	1.5	1.0	0.8	1.1	1.6	1.2	0.9	1.6
Phosphorus as phosphate (g/day)	1961	3.7	4.4	5.7	4.9	3.5	4.0	4.3	—	5.5	—	6.4
	1962	3.7	3.3	6.2	3.7	3.7	3.5	3.9	5.2	4.5	3.6	7.4
	1963	3.1	4.3	4.2	4.4	3.6	3.1	3.4	5.7	3.7	2.9	6.1
	1964	—	—	—	—	—	—	—	—	—	—	—
Potassium (g/day)	1961	2.9	2.1	2.8	2.4	2.1	3.1	2.5	—	3.1	—	3.1
	1962	2.5	2.3	3.8	2.2	2.0	2.4	3.5	3.1	3.5	2.0	5.4
	1963	2.7	2.9	3.6	2.6	1.8	2.5	2.6	3.4	2.8	2.7	4.4
	1964	2.1	2.8	3.7	2.6	2.3	2.3	2.4	3.5	2.6	2.5	3.4
Total radium (pCi/day)	1961	4.9	5.4	7.1	7.8	5.1	14.5	7.4	—	9.0	—	7.2
	1962	1.8	1.7	5.3	2.8	2.5	6.1	1.7	2.8	2.6	1.9	6.2
	1963	[a]	[a]	[b]	4.3	3.6	[a]	[c]	4.6	[c]	[b]	[b]
Radium-226	1964	1	1	2	[c] 4.3	[c] 3.4	2	1	[c] 6.3	1	1	2
Strontium-89 (pCi/day)	1961	—	—	—	17	7	—	11	—	45	—	—
	1962	42	10	66	11	48	17	13	120	18	60	152
	1963	18	12	24	38	54	35	19	182	15	27	62
	1964	10	5	10	5	10	10	5	10	5	10	15
Strontium-90 (pCi/day)	1961	5	5	7	10	7	5	7	—	16	—	8
	1962	12	4	19	10	12	8	5	29	11	13	25
	1963	19	9	25	22	23	11	39	46	34	17	35
	1964	30	17	31	29	38	18	21	67	34	32	48
Cesium-137 (pCi/day)	1961	46	11	25	134	13	32	14	—	20	—	22
	1962	42	11	70	43	34	39	70	77	96	50	52
	1963	140	74	137	268	112	97	153	221	228	128	194
	1964	155	90	150	295	120	125	140	225	260	145	150
Barium-140 (pCi/day)	1961	27	16	20	19	16	27	16	—	21	—	23
	1962	21	16	27	20	19	39	12	26	17	36	60
	1963	10	10	10	25	24	10	15	29	15	10	10
	1964	0	0	0	0	0	0	0	0	0	0	0
Iodine-131 (pCi/day)	1961	19	6	11	22	27	42	38	—	85	—	6
	1962	49	12	22	20	22	36	14	29	18	26	25
	1963	15	15	10	25	24	10	15	29	15	12	10
	1964	0	0	0	0	0	0	0	0	0	0	0

Dash indicates no analysis.

[a] Total radium reported for January—August 1963; radium-226 reported the remainder of the year. Monthly averages for total radium ranged from <1–12 during the period from January—August. Monthly averages for radium-226 ranged <1–5 during the remainder of the year.

[b] Total radium reported for January—July 1963; radium-226 reported the remainder of the year. Monthly averages for total radium ranged from <1–3 during the period from January—July 1963. Monthly averages for radium-226 ranged from <1–4 during the remainder of the year.

A frequency distribution of dietary intake was developed for each year (table 2). Over the 4-year period the average dietary intake was 1.90 kg/day (figure 1). The distribution approaches that of a normal distribution and has a standard deviation of 0.43 kg/day. It is noted that the individual yearly average intakes were within 3 percent of the 4-year average.

Table 2. Frequency distribution of annual average dietary intake, 1961–1964

Range (kg/day)	Number of stations				Total	
	1961	1962	1963	1964	Number	Percent
1.30–1.59	2	8	4	3	17	22
1.60–1.89	3	5	10	6	24	31
1.90–2.19	5	3	2	7	17	22
2.20–2.49	3	1	4	4	12	16
2.50–2.79	1	2	1	1	5	6
2.80–3.09		2			2	3
Total	14	21	21	21	77	100
Average	1.96	1.88	1.84	1.92	—	—

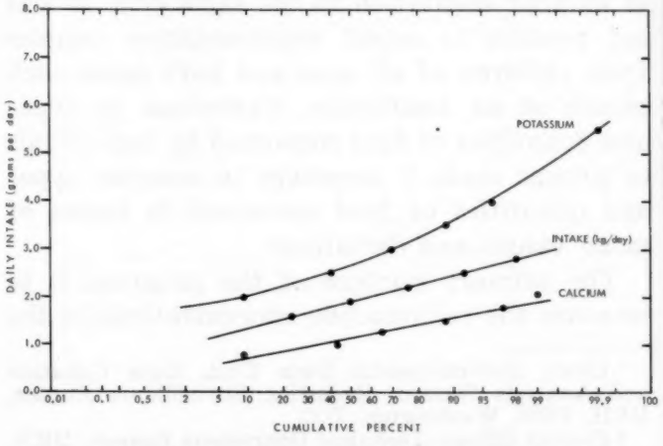

Figure 1. Cumulative frequency distribution of daily dietary, calcium, and potassium intakes

Montana, Helena	Nebraska, Omaha	New Mexico, Albuquerque	New York, New York	Ohio, Cleveland	Tennessee, Memphis	Texas, Austin	Utah, Salt Lake City	Virginia, Norfolk	Washington, Seattle	All institutions average	Year	
—	—	—	10	—	3	11	2	—	11		1961	Number of samples.
10	11	12	6	12	12	12	9	12	12		1962	
12	11	11	8	12	12	12	9	12	12		1963	
12	12	12	4	12	12	12	10	12	12		1964	
—	—	—	1.35	—	1.95	2.47	2.13	—	2.29	1.96	1961	Total weight (kg/day).
2.46	1.71	1.58	1.45	1.75	1.59	2.66	1.43	1.48	2.80	1.88	1962	
1.51	1.82	1.71	1.69	1.89	1.60	2.32	1.48	1.55	2.37	1.84	1963	
2.02	2.03	1.92	1.74	1.95	1.60	1.95	1.42	2.19	1.90	1.92	1964	
—	—	—	0.7	—	1.2	1.5	0.8	—	1.5	1.1	1961	Calcium (g/day).
1.5	1.1	1.1	0.7	1.2	0.9	1.5	0.9	0.7	2.1	1.2	1962	
0.8	1.2	1.3	1.5	1.4	1.1	1.3	0.9	0.8	1.4	1.1	1963	
1.0	1.6	1.6	1.4	1.2	1.0	1.0	0.9	1.1	1.2	1.2	1964	
—	—	—	2.9	—	4.3	6.1	4.4	—	6.4	4.8	1961	Phosphorus as phosphate (g/day).
5.8	4.3	4.1	2.7	4.1	3.5	6.3	3.1	3.3	6.9	4.4	1962	
3.1	3.9	4.0	4.0	5.3	3.6	5.8	3.2	3.5	5.5	4.1	1963	
—	—	—	—	—	—	—	—	—	—	—	1964	
—	—	—	2.0	—	2.8	3.2	3.1	—	3.0	2.7	1961	Potassium (g/day)
3.5	2.7	2.6	2.5	3.8	2.5	2.7	2.3	1.9	4.6	3.0	1962	
2.4	3.1	2.9	3.0	3.3	2.4	3.0	2.7	2.0	3.6	2.9	1963	
2.4	2.9	2.9	2.8	3.2	2.0	2.1	2.2	2.4	2.8	2.7	1964	
—	—	—	3.7	—	8.9	9.5	10.1	—	7.7	7.7	1961	Total radium (pCi/day).
3.9	2.4	1.7	2.4	2.5	2.2	2.6	2.4	2.4	6.1	3.0	1962	
[a]	[a]	[a]	[c]	[c]	2.9	3.9	[a]	2.7	[a]	[d]	1963	
1	2	1	1	1	[c]3.0	2.9	1	[c]4.3	1	[d]	1964	Radium-226.
—	—	—	2	—	105	18	—	—	—	29	1961	Strontium-89 (pCi/day).
67	35	18	8	11	59	57	38	63	105	48	1962	
21	38	18	12	16	72	71	15	42	72	41	1963	
10	5	5	0	5	5	5	5	10	10	7	1964	
—	—	—	6	—	13	10	7	—	7	8	1961	Strontium-90 (pCi/day).
13	9	5	5	7	14	16	7	13	27	13	1962	
17	25	12	27	35	27	26	13	21	32	25	1963	
30	39	24	27	26	32	20	26	34	43	32	1964	
—	—	—	16	—	15	14	15	—	34	29	1961	Cesium-137 (pCi/day).
56	24	17	20	67	17	69	38	29	100	49	1962	
126	125	44	131	135	90	108	130	81	215	140	1963	
190	140	80	170	170	80	70	155	130	200	154	1964	
—	—	—	13	—	20	25	21	—	26	21	1961	Barium-140 (pCi/day).
73	17	30	14	15	20	29	17	18	39	27	1962	
10	15	10	13	14	23	29	18	23	22	16	1963	
0	0	0	0	0	0	0	0	0	0	0	1964	
—	—	—	5	—	53	14	34	—	22	27	1961	Iodine-131 (pCi/day).
24	23	55	14	19	21	35	15	17	40	25	1962	
10	10	10	13	15	23	29	10	23	14	16	1963	
0	0	0	0	0	0	0	0	0	0	0	1964	

[c] Total radium reported for January—June 1963; radium-226 reported the remainder of the year. Monthly averages for total radium were <1 from the period from January—June 1963. Monthly averages for radium-226 ranged from <1–2 during the remainder of the year.

[d] Average for all institutions is not given since total radium was reported for a number of institutions for part of the year and radium-226 for the remainder of the year.

[e] Average represents total radium since radium-226 was not determined.

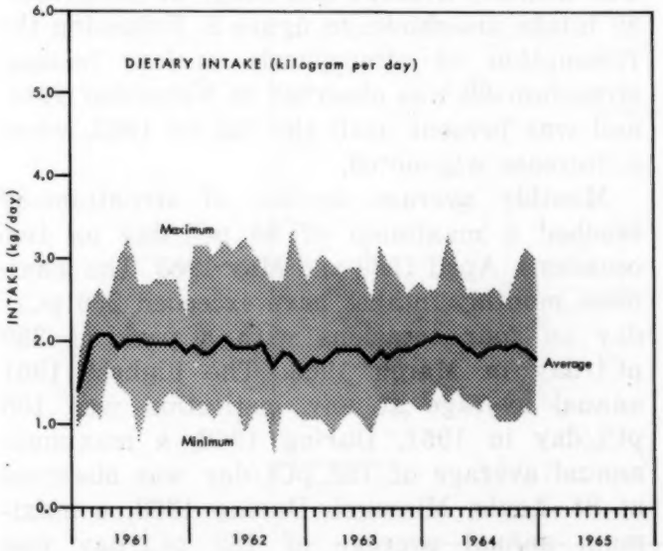

Figure 2. Range and average dietary intake per month

The monthly network average and range of dietary intake (figure 2) show a uniform dietary intake with no apparent seasonal variations. Maximum and minimum intakes are fairly constant. The maximum institutional value observed between 1961 and 1964 was 3.4 kg/day in November 1962. The minimum value was 0.6 kg/day in September 1962.

Calcium and potassium

As with dietary intake, a frequency distribution of calcium intake was developed (table 3). Over the 4-year period the average calcium intake was 1.13 g/day (figure 1). This distribution is observed to approach that of a normal distribution with a standard deviation of 0.33

g/day. The monthly network average and range of calcium intake are shown is figure 3. Although the monthly average exhibits no seasonal variation, an apparent fall peak is observed in the maximum intake. A maximum calcium intake of 3.6 g/day was observed in October 1961, with occasional minima of 0.2 g/day.

Table 3. Frequency distribution of annual average calcium intakes, 1961–1964

Range (g/day)	Number of institutions				Total	
	1961	1962	1963	1964	Number	Percent
<0.75	3	2	2		7	9
0.75–0.99	4	8	6	8	26	34
1.00–1.24	4	3	4	6	17	22
1.25–1.49	2	5	8	3	18	23
1.50–1.74	1	1	1	4	7	9
1.75–1.99		1			1	1
>2.00		1			1	1
Total	14	21	21	21	77	99
Average	1.1	1.2	1.1	1.2	—	—

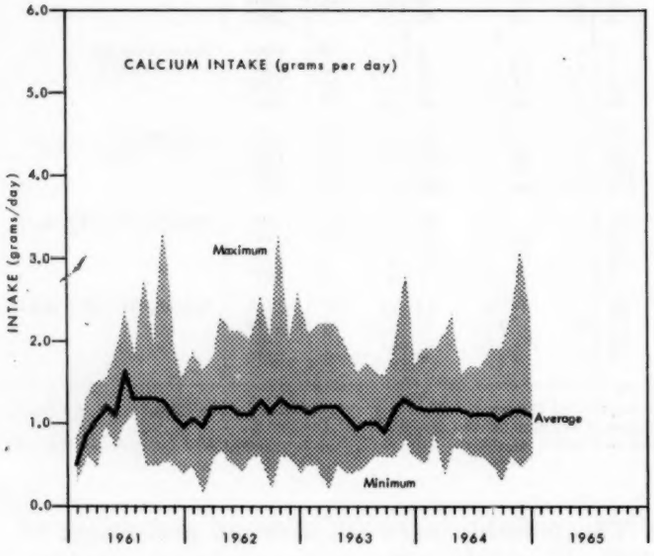

Figure 3. Range and average calcium intake per month

Annual average potassium intakes are given in table 4 as a frequency distribution. Figure 1 shows an average potassium intake of 2.7 g/day over the 4-year period of concern. Unlike dietary intake and calcium intake, the potassium distribution is skewed from that of a normal distribution toward higher intake values. Network monthly average and range of potassium intake are presented in figure 4. The average remains fairly uniform with no apparent seasonal variation. The minimum rarely falls below 1 g/day. The maximum exhibits an apparent spring rise, rarely exceeding 6 g/day.

Table 4. Frequency distribution of annual average potassium intakes, 1961–1964

Range (g/day)	Number of institutions				Total	
	1961	1962	1963	1964	Number	Percent
1.50–1.99	1	3	2	1	7	9
2.00–2.49	4	7	3	10	24	31
2.50–2.99	4	2	10	6	22	29
3.00–3.49	5	4	3	3	15	19
3.50–3.99		3	2	1	6	8
4.00–4.49			1		1	1.3
4.50–4.99		1			1	1.3
5.00–5.49		1			1	1.3
Total	14	21	21	21	77	99
Average	2.7	3.0	2.9	2.7	—	—

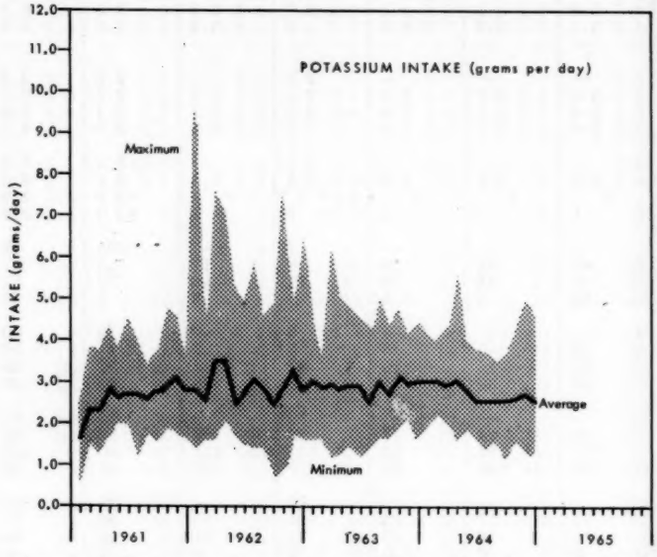

Figure 4. Range and average potassium intake per month

Strontium–89

Strontium–89 analysis was introduced in September 1961, at which time concentrations were below the detectable limit (10 pCi/kg). The monthly average and range of strontium–89 intake are shown in figure 5. Following the resumption of atmospheric nuclear testing, strontium–89 was observed in November 1961, and was present until the fall of 1963, when a decrease was noted.

Monthly average intakes of strontium–89 reached a maximum of 80 pCi/day on two occasions, April 1962 and May 1963. The maximum monthly intakes have exceeded 250 pCi/day on four occasions with a peak of 350 pCi/day in March 1963. The highest 1961 annual average at any institution was 105 pCi/day in 1961. During 1962, a maximum annual average of 152 pCi/day was observed at St. Louis, Missouri. During 1963, a maximum annual average of 182 pCi/day was observed at New Orleans, Louisiana.

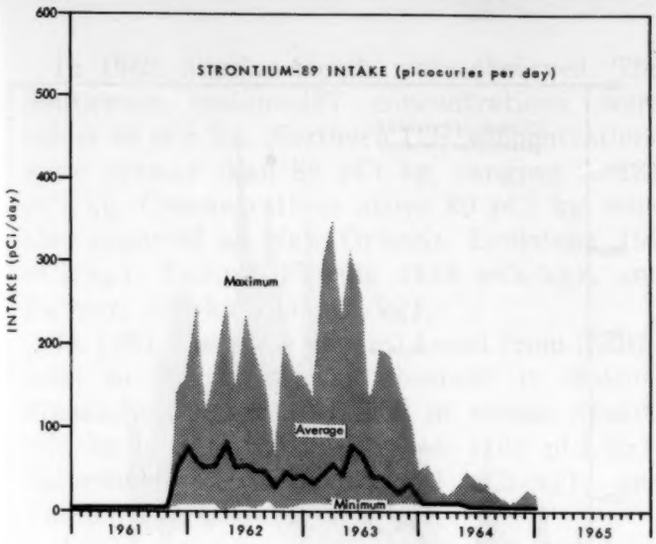

Figure 5. Range and average strontium–89 intake per month

Strontium–90

During the first 8 months of 1961 the average strontium–90 intake was 8 pCi/day (figure 6). Thereafter, a steady increase was observed until April 1964 at a rate of approximately 10 pCi/day·year. At that time a decreasing trend ensued. Similar trends were observed in the FDA Teenage Diet Survey (*4*) and the HASL Tri-City Diet Study (*5*). The highest monthly strontium–90 intake observed was 100 pCi/day in July 1963. This is within Range II (20 to 200 pCi/day) as defined by the Federal Radiation Council (*2*).

Annual average ranges were in 1961, 5 to 16 pCi/day; 1962, 4 to 29 pCi/day; 1963, 9 to 39 pCi/day; and 1964, 17 to 67 pCi/day. The 1963 maximum was in Chicago, Illinois; the 1964 maximum was in New Orleans, Louisiana.

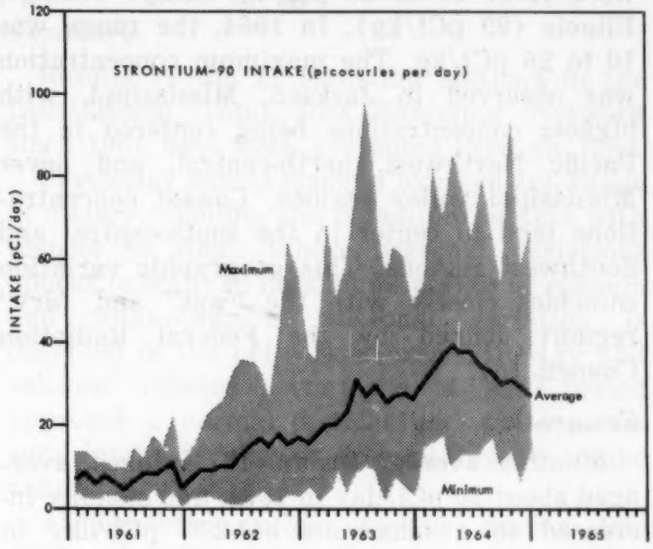

Figure 6. Range and average strontium–90 intake per month

Discussion of the results on a regional basis is more meaningful on a pCi/kg basis than a pCi/day basis, since differences in daily intakes of radionuclides may be mainly due to differences in the amounts of food consumed (*5*). The strontium–90 results on a pCi/kg basis are presented in figure 7. The observed concentra-

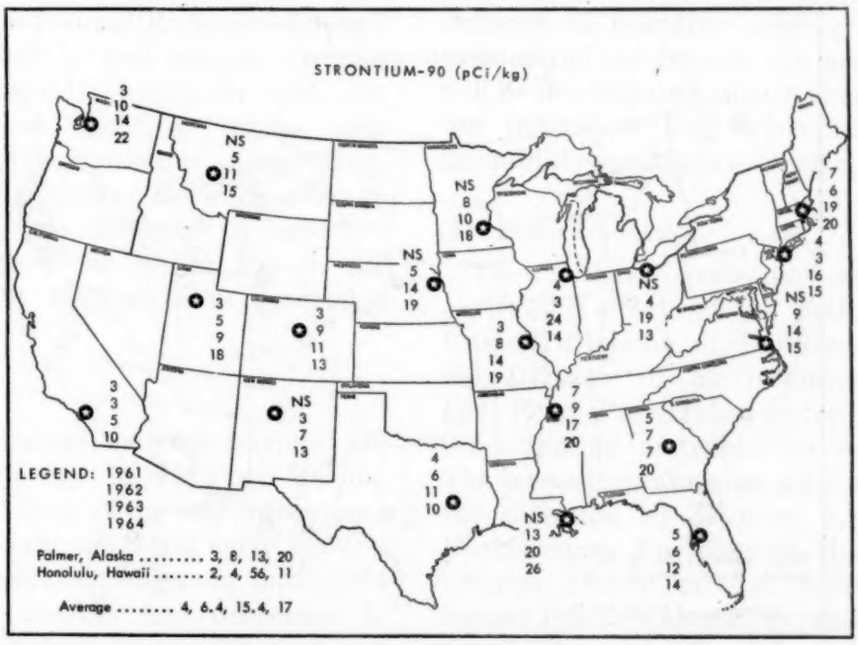

Figure 7. Annual average strontium–90 concentration in total diet, 1961–1964

tion ranges were: 1961, 3 to 7 pCi/kg; and 1962, 3 to 13 pCi/kg. In 1963 the Southwest and Atlanta, Georgia, reported an average below 10 pCi/kg; all other station averages were from 10 to 20 pCi/kg except Chicago, Illinois (29 pCi/kg). In 1964, the range was 10 to 26 pCi/kg. The maximum concentration was observed in Jackson, Mississippi, with highest concentrations being centered in the Pacific Northwest, north-central, and lower Mississippi valley regions. Lowest concentrations tend to center in the south-central and Southwest regions. This geographic variation coincides closely with the "wet" and "dry" regions defined by the Federal Radiation Council (*6*).

Cesium–137

Monthly average cesium–137 intakes, averaged about 20 pCi/day in 1961, and steadily increased to a maximum of 200 pCi/day in March 1964 (figure 8). Network annual averages increased from 29 pCi/day in 1961 to 154 pCi/day in 1964. The maximum intake reached 565 pCi/day in December 1963. This is well below 4400 pCi/day derived from International Committee on Radiological Protection recommendations as applied to the population at large (*7*).

To evaluate regional differences, results are presented graphically in figure 9. In 1961, four

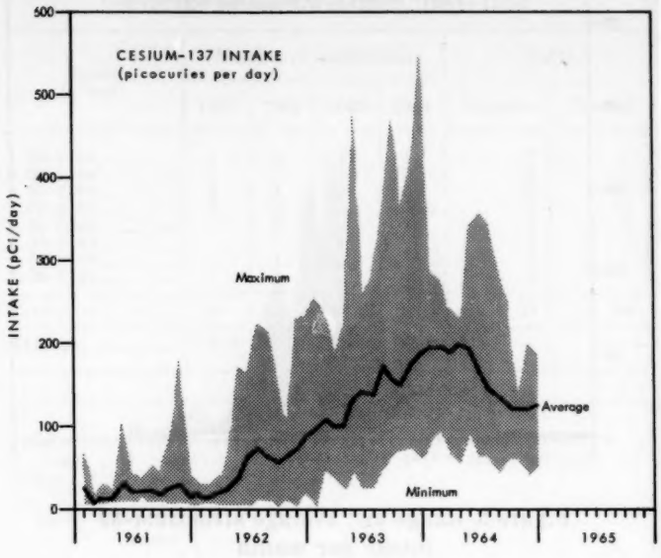

Figure 8. Range and average cesium–137 intake per month

institutions reported average cesium–137 concentrations greater than 5 pCi/kg, the maximum being 7 pCi/kg. In 1962, the maximum concentrations were 51 pCi/kg. Proceeding from Southwest to Northeast stratified belts can be inferred: Southwest concentrations were below 20 pCi/kg; adjacent areas showed an increasing trend with higher concentrations occurring in the Great Lakes area, followed by a maximum concentration of 51 pCi/kg, in the Northeast.

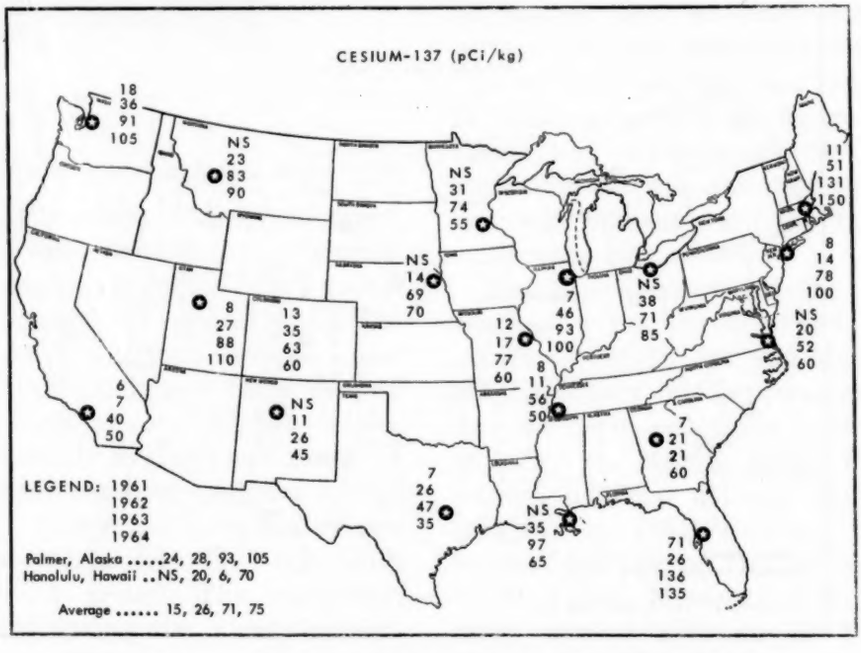

Figure 9. Annual average cesium–137 concentration in total diet, 1961–1964

In 1963, similar trends were observed. The Southwest cesium–137 concentrations were below 40 pCi/kg. Northern U.S. concentrations were greater than 80 pCi/kg, ranging to 131 pCi/kg. Concentrations above 80 pCi/kg were also reported at New Orleans, Louisiana (97 pCi/kg), Tampa, Florida (136 pCi/kg), and Palmer, Alaska (93 pCi/kg).

In 1964, the same general trend from Southwest to Northeast was observed in Boston, Massachusetts, with values in excess of 100 pCi/kg in Seattle, Washington (105 pCi/kg), Salt Lake City, Utah (110 pCi/kg), and Tampa, Florida (135 pCi/kg).

An increase in cesium–137 intake has been seen from 1961 through early 1964. Current results indicate that the peak has occurred and a general decreasing trend can be expected to ensue. Comparable trends have been observed in the FDA Teenage Diet Survey (*4*).

Iodine–131

Iodine–131 concentrations for 1961 reflect a 4-month average since iodine–131 was not observed prior to September 1961. The maximum annual average intake of iodine–131 observed in 1961 was 85 pCi/day at Boston, Massachusetts. In 1962, the maximum was 55 pCi/day at Albuquerque, New Mexico. From September 1961 through December 1962 (16 months) the maximum daily intake of iodine–131 exceeded 100 pCi, the top of Range II as recommended by the Federal Radiation Council (*2*). However, monthly and annual average intakes were significantly lower. In 1963, the maximum individual monthly intake was 70 pCi/day, while the maximum annual average intake was 29 pCi/day. Network average iodine–131 intakes are observed to have decreased steadily since the initial rise in the fall of 1961, and by 1964 to below detectable levels.

Barium–140

The maximum annual average barium–140 intake was 73 pCi/day in 1962 at Helena, Montana. Since the time of the rise in barium–140 intake during late 1961 and early 1962, a decreasing trend has been observed until 1964 when barium–140 intakes had decreased to below detectable levels. Using International Committee on Radiation Protection (ICRP) maximum permissible concentrations in water for the population at large, the corresponding intake of barium–140 was 22,000 pCi/day (*7*). Observed barium–140 intakes were well below this value.

Summary

Results of the 21 sampling stations in the Institutional Total Diet Sampling Network since 1961 have been presented through 1964.

Particular note is made of average and range of dietary, calcium, and potassium intakes with respect to time. Where seasonal variations appear to occur in maximum intakes of calcium and potassium, no seasonal variation is observed in the network average. Dietary and calcium intakes over the 4-year period approach a normal distribution, while potassum intake is skewed toward higher intake values.

Atmospheric nuclear testing during late 1961 and 1962 resulted in a general increasing trend for radionuclide levels until 1964. Maximum intake of shorter-lived nuclides such as strontium–89, iodine–131, and barium–140 occurred during 1962 or 1963 and intakes were below detectable levels by 1964. The apparent decreases in strontium–90 and cesium–137 intakes which ensued in the fall of 1964 can be expected to continue with the cessation of atmospheric nuclear testing.

Extrapolation of the observed intakes of children in boarding schools and institutions to those of children in the general population will be investigated at such time as data regarding individual food consumption (based on probability sampling) become available.

Acknowledgements

The authors gratefully acknowledge the continuing efforts of the Technical Operations Branch, Division of Radiological Health and the Division of Environmental Engineering and Food Protection, under whose direction the sampling and analyses were carried out. The laboratory analyses were performed under the direction of Edmond J. Baratta of the Northeastern Radiological Health Laboratory, Charles Porter of the Southeastern Radiological Health Laboratory, and Ewald Pyzel of the Southwestern Radiological Health Laboratory, DRH.

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ESTIMATED DAILY INTAKE OF RADIONUCLIDES IN CALIFORNIA DIETS,[1] NOVEMBER–DECEMBER 1964

Bureau of Radiological Health
California State Department of Public Health

Since January 1964, the Bureau of Radiological Health, California State Department of Public Health, has made estimates of radionuclide levels in the diets of Californians (*1*).

Recognizing that a "standard" or "typical" diet does not exist, due to variations in individual tastes, an effort was made to select a diet which was reasonably representative of the food consumed in a given area. This objective was met by utilizing the "house" diet of a hospital in each of the 20 geographic areas of interest.

Hospitals were chosen as the source of diet samples under the hypothesis of their being as "reasonably representative" as any other source. General hospitals exist in each of the selected geographic areas and operate with trained dietitians. There is good reason to believe that hospitals utilize foods which are marketed in their respective communities. Also, working relations for entry into hospitals existed through the State Bureaus of Nutrition and Hospitals.

[1] This work was summarized under the supervision of Amasa C. Cornish, Senior Health Physicist, Jack L. Brown, Associate Health Physicist, and George Barr, Radiological Health Specialist, Bureau of Radiological Health, California State Department of Public Health.

Sampling procedure

In general, the sampling procedure is the same at each hospital. Samples are collected once every 2 months at each facility. Each sample represents the edible portion of a regular meal (the standard diet) for a full 7-day week (21 consecutive meals).

After each sample is collected, it is suitably preserved and shipped to the Sanitation and Radiation Laboratory. Accompanying each sample is a record prepared by the dietitians indicating the types and quantities of food included.

Analytical procedures

After weighing at the laboratory, each sample is homogenized, dried, and ashed prior to stable calcium, potassium, strontium, and sodium determination being made.

The radiochemical analyses are based upon three basic procedures: chemical separations of strontium–89 and strontium–90; analysis of radium–226; and gamma spectroscopy of 1 gallon of wet sample.

Data and discussion

The resultant estimates of daily intake of radionuclides in the California diets are given in table 1 for November through December 1964 (*2*).

Table 1. Estimated daily intake of radionuclides in California diets, [a] November–December 1964

City	Kg/capita per day [b]	pCi/capita • day							Grams/capita • day			
		^{89}Sr	^{90}Sr	^{226}Ra	^{137}Cs	^{95}Zr	^{54}Mn	^{141}Ce, ^{144}Ce	K [c]	Na	Ca	Stable Sr [d]
Bakersfield	2.2	0	13	1.1	53	[e] 13	0	0	2.8	3.4	1.1	0.002
Berkeley	2.7	0	10	1.2	60	20	0	0	1.8	2.5	0.7	0.001
Bishop	1.6	0	12	0.4	47	0	0	0	2.2	2.6	0.5	0.001
Brawley	NS											
Crescent City	2.2	0	36	0.8	120	17	0	0	2.8	4.7	0.9	0.002
Eureka	2.2	0	23	0.6	55	10	0	0	3.0	2.7	1.3	0.001
Fresno	2.2	0	11	3.5	83	39	0	0	2.2	3.4	1.0	0.002
Los Angeles	2.6	0	10	1.2	73	16	0	0	2.9	3.9	0.7	0.002
Needles	1.7	0	12	1.1	43	[e] 3	0	0	2.5	3.5	0.8	0.002
Quincy	1.8	0	10	1.2	93	15	0	0	2.5	3.4	0.6	0.002
Redding	2.2	0	16	1.1	57	[e] 4	0	0	2.8	5.0	0.8	0.002
Sacramento	2.1	0	12	0.7	71	17	0	0	2.5	4.4	0.7	0.001
Salinas	NS											
San Bernardino	2.2	0	14	0.9	56	18	0	0	3.4	4.3	1.2	0.001
San Diego	2.1	0	12	0.2	38	5	0	0	3.3	3.6	0.9	0.001
San Luis Obispo	1.5	0	18	1.0	68	28	0	0	2.1	3.8	0.8	0.002
Santa Barbara	NS											
Santa Rosa	2.2	0	18	0.2	98	[e] 3	0	0	3.0	3.5	1.4	0.001
Susanville	NS											
Ukiah	2.3	0	28	2.1	94	38	0	0	3.0	3.2	1.8	0.002

[a] Based on analyses of hospital standard diets located in listed cities.
[b] Kilograms of food per person per day in this diet.
[c] Natural potassium contains 0.0119 percent of radioactive K-40.
[d] Stable strontium consists of strontium-88 (82.7 percent), strontium-87 (7.0 percent), strontium-86 (9.8 percent), strontium-84 (0.5 percent).
[e] Count rate was less than or equal to twice the 95 percent error; the value reported is the best estimate.
NS, sample lost in laboratory procedures.

It should be noted that levels of radioactivity were observed to be far below those levels for which consideration should be given to protective health action.

Averages for the year have been calculated for all the hospitals. The yearly averages for the selected nuclides, strontium–90, cesium–137, and radium–226 are shown in table 2.

Table 2. Annual average dietary intakes in California, 1964

City	Average intake, pCi/capita • day		
	Strontium-90	Cesium-137	Radium-226
Bakersfield	15	73	1.2
Berkeley	19	64	0.9
Bishop	13	49	0.9
Brawley	9	47	1.3
Crescent City	48	120	1.7
Eureka	22	70	1.3
Fresno	28	62	1.7
Los Angeles	13	76	1.1
Needles	16	52	1.2
Quincy	13	75	1.0
Redding	19	58	1.3
Sacramento	18	74	1.6
Salinas	16	78	0.9
San Bernardino	15	51	1.0
San Diego	14	52	0.9
San Luis Obispo	14	44	0.9
Santa Barbara	15	51	1.0
Santa Rosa	21	72	1.0
Susanville	17	89	0.6
Ukiah	21	72	1.1

The 1964 annual average strontium–90 intake in the California diet varied from 9 to 48 picocuries per capita per day with a mean of 18 picocuries per capita per day. The general trend was from high in the northern part to low in the southern part of the State.

Cesium–137 intakes varied from 47 to 120 picocuries per capita per day. As with strontium–90, highest values occurred in the north and lowest values in the south.

Radium–226 intakes varied from 0.6 to 1.7 picocuries per capita per day. The highest values were in the northern coastal and central regions of the State. Higher values were observed to form a broad band running from northwest to southeast. Lowest values were observed near the eastern border of the State north of and including Inyo County, and in the coastal region south of Humbolt County.

A comparison of strontium–90 intakes with the Tri-City Diet Study (table 3) indicates that

Table 3. Strontium-90 in California and Tri-City Diet studies, 1964

Study and location	Strontium-90 (pCi/capita • day)
California Diet study:	
San Francisco	19
State average	18
State maximum	48
State minimum	9
Tri-City Diet study:	
San Francisco	14

San Francisco daily intakes for 1964 were 19 picocuries per capita per day for the California Diet Study, and 14 picocuries per capita per day for the Tri-City Diet Study (*3*). These values are observed to be in close agreement.

The magnitude of the observed intakes of strontium–90, cesium–137 and radium–226 in California diets were so low that no public health actions were indicated during 1964.

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SELECTED RESULTS FROM TOTAL DIET STUDIES,[1] FEBRUARY 1963–JUNE 1964

Since November 1959, the Consumers Union (CU) has engaged in studies of the radionuclide content of samples of teenagers' total diet collected during various periods of the year from groups in selected U.S. cities (*1–7*). It is believed that the selection of the teenager group for study will produce estimates of dietary radionuclide intake which are not likely to be exceeded by the general population. A basis for this is found in the National Research Council's recommended dietary allowances (*8*), which establish the relatively high nutritional needs of teenagers as compared with other age groups.

Originally, diet samples from 25 U.S. cities were analyzed; with the January 1962 sampling, the number of cities included was increased to 30. This report deals with analyses of diets from 23 cities, five of which have been sampled since the beginning of the program, and ten from the period May 1961 through June 1964. Comparisons of 1964 results to those of the Public Health Service Institutional Total Diet Sampling Network were published earlier (*9*).

[1] Based on data from studies performed by Mr. Irving Michelson, formerly Director of Public Service Projects, Consumers Union, in fulfillment of Public Health Service contracts SAph 76694 and PH 86–64–71 and HASL–AEC Contract No. AT (30–1)–3187.

[2] Analyses were performed by PHS Northeastern, Southeastern and Southwestern Radiological Health Laboratories and by Isotopes, Inc., Westwood, New Jersey.

Sampling procedures

Each diet sample from a city consisted of the total diet (food, milk, and drinking water) of teenagers for a full week (21 meals plus snacks). To help assure that the various diet samples were representative of the region in which the selected city was situated, home economists in universities were asked to prepare, based on local surveys, diets comparable to the average male teenage diet within their area. The home economist, where feasible, purchased fresh produce in local markets; frozen and canned items were substituted only when necessary.

Typical items in the menus were: hot and cold cereal, eggs, bread, milk, and other dairy products, spaghetti, beef, lamb, pork, chicken, fish, salads, vegetables, soups, fruits, fruit juices, and drinking water. Also included were snacks containing soft drinks, candy, cookies, sandwiches, cake, and ice cream. Meals were prepared as though for actual consumption with inedible parts discarded. After preparation, samples were shipped to the participating laboratories[2] for analysis. Split samples were used for cross-checking the laboratories' results. For the 10 cities continuously sampled, separate milk samples were analyzed to determine the milk contribution to the total dietary intake.

Analytical program and methods

The program included analysis of each sample for stable calcium and potassium, strontium–89, strontium–90, and cesium–137. The calcium analysis has been derived from a procedure described by Yalman *et al.* (*9*). Strontium–90 was determined by beta counting its daughter, yttrium–90, which had been chemically separated from the sample. Cesium–137 determinations were made by either gamma counting directly or beta counting after chemical separation.

Sampling results

Table 1 presents the average daily dietary intake for 1963 and the first half of 1964. The total weight of food consumed ranged between 1.84 and 5.44 kg/day with most intakes falling between 3 and 4 kg/day. The daily calcium intake (table 2) ranged between 0.9 and 3.2 g/day, with approximately 80 percent of the intakes falling between 1.5 and 2.5 g/day. The daily potassium intake (table 3) ranged between 3.20 and 7.66 g/day during the period February through June 1964.

Strontium–89 intake averages (table 4) show that New Orleans, Louisiana, has consistently reported higher levels than the other cities. The maximum reported intake value was 320 pCi/day. During 1963, strontium–89 intakes were seen to steadily decrease. Similar results were observed in the Institutional Total Diet Sampling Network (*10*).

Table 1. Average daily dietary intake (kg/day) 1963–1964

Sampling locations		1963								1964			
		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb	Apr	May	Jun
Ala:	Tuscaloosa	3.89		3.16		4.14			4.11				
Ariz:	Grand Canyon			4.44		4.27			2.86				
Ark:	Little Rock	2.47	3.56	2.60	2.46	2.41	3.24	3.50	2.89				
Calif:	Los Angeles	4.09	4.09	3.47	4.73	3.83	3.76	4.09	2.76	4.76	4.39	4.01	3.89
	San Francisco	4.60	4.14	3.24	4.14	4.27	3.63	3.24	3.01				
Idaho:	Boise	2.40				4.19			3.01				
Ill:	Chicago	3.90	3.63	3.69	4.07	3.71	3.57	3.44	3.87	3.63	4.33	3.63	3.66
La:	New Orleans	3.17	2.99	3.31	3.43	3.39	3.63	2.99	3.09	2.91	3.20	3.89	3.09
Maine:	Portland	1.84		3.24		3.66			3.40				
Minn:	Duluth	3.84	3.69	3.73	3.50	4.04	3.37	3.06	4.40				
Mo:	St. Louis	4.73		4.80		3.80			3.49	3.91	4.11	3.39	3.64
Nev:	Reno	4.09		3.60		3.50			3.01				
N. Y:	Buffalo	4.06		3.63		3.44			3.54	3.79	3.97	2.24	3.31
	New York	2.97	3.69	3.67	3.56	3.53	3.63	3.57	3.41	3.43	4.70	3.57	3.59
N. Dak:	Bismark	4.99		4.21		3.24			2.86	3.27	3.64	3.17	2.77
Okla:	Oklahoma City	4.29		3.49		2.73			3.27				
Ore:	Portland	3.11	4.21	3.63	4.53	3.89	3.54	3.44	2.89	4.37	4.37	3.23	4.20
S. C:	Columbia	2.81		3.11		3.17			2.86				
S. Dak:	Sioux Falls	3.64	4.01	3.47	3.37	3.44	4.03	2.86	3.40				
Tenn:	Knoxville	4.24	3.40	3.61	3.89	3.53	3.44	3.63	3.39	4.24	4.13	3.91	4.37
Utah:	Salt Lake City									3.70	4.27	3.43	3.54
W. Va:	Charleston	4.61		4.34		3.91			3.29				
Wyo:	Casper	5.44		3.34		3.43			2.30				
Average		3.77	3.74	3.61	3.77	3.61	3.58	3.38	3.23	3.80	4.11	3.45	3.61

Blanks indicate no sample collected.

Table 2. Average daily calcium intake (g/day), 1963–1964

Sampling locations		1963								1964			
		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb	Apr	May	Jun
Ala:	Tuscaloosa	2.3		1.8		2.1			1.7				
Ariz:	Grand Canyon			2.0		1.7			1.3				
Ark:	Little Rock	1.7	2.1	1.6	1.4	1.5	2.0	2.0	1.8				
Calif:	Los Angeles	1.6	2.0	1.8	2.0	1.9	1.7	1.7	1.4	2.5	2.1	2.3	1.9
	San Francisco	2.4	2.6	1.6	2.3	2.0	1.9	1.7	1.4				
Idaho:	Boise	1.4				1.9			1.5				
Ill:	Chicago	2.4	1.9	2.2	2.1	2.0	2.1	1.8	2.0	2.4	2.4	1.9	2.2
La:	New Orleans	1.8	1.9	2.0	1.9	1.7	2.0	1.4	1.9	1.9	2.0	2.1	1.9
Maine	Portland	0.9		1.7		1.9			1.9				
Minn:	Duluth	2.0	1.8	2.2	1.7	2.1	1.5	1.5	2.2				
Mo:	St. Louis	2.6		2.6		2.3			2.0	2.3	2.3	2.0	2.3
Nev:	Reno	2.0		2.0		1.6			1.5				
N. Y:	Buffalo	2.3		2.1		1.9			2.1	2.1	2.0	1.8	1.9
	New York	1.8	1.8	2.1	1.7	2.0	2.1	1.8	2.6	2.2	2.6	1.8	2.0
N. Dak:	Bismark	2.2		2.3		2.4			1.5	2.2	2.1	2.0	1.6
Okla:	Oklahoma City	2.6		1.9		1.1			1.8				
Ore:	Portland	1.5	2.5	2.0	2.1	2.0	1.8	1.7	1.6	3.0	2.3	2.6	2.3
S. C:	Columbia	2.0		2.1		1.9			1.9				
S. Dak:	Sioux Falls	1.9	2.1	1.8	1.6	1.8	2.3	1.4	1.9				
Tenn:	Knoxville	2.1	1.9	2.1	2.1	2.1	2.1	2.4	2.3	2.8	2.4	2.3	3.2
Utah:	Salt Lake City									2.4	2.4	2.0	2.2
W. Va:	Charleston	2.3		2.3		2.3			1.7				
Wyo:	Casper	2.9		1.8		1.5			1.1				
Average		2.0	2.1	2.0	1.9	1.9	2.0	1.7	1.8	2.4	2.3	2.1	2.2

Table 3. Average daily potassium intake (g/day), 1964

Sampling locations		1964			
		Feb	Apr	May	Jun
Ala:	Tuscaloosa				
Ariz:	Grand Canyon				
Ark:	Little Rock				
Calif:	Los Angeles	7.66	6.80	6.02	5.41
	San Francisco				
Idaho:	Boise				
Ill:	Chicago	4.32	5.80	4.97	4.80
La:	New Orleans	3.20	3.48	4.90	3.55
Maine:	Portland				
Minn:	Duluth				
Mo:	St. Louis	5.38	5.35	4.75	4.00
Nev:	Reno				
N.Y:	Buffalo	5.08	5.60	4.18	3.54
	New York	5.25	7.05	5.07	4.52
N. Dak:	Bismark	4.38	5.27	4.03	3.96
Okla:	Oklahoma City				
Ore:	Portland	7.14	6.47	6.18	5.04
S. C:	Columbia				
S. Dak:	Sioux Falls				
Tenn:	Knoxville	5.34	5.74	5.90	6.03
Utah:	Salt Lake City	6.00	6.58	4.15	4.81
W. Va:	Charleston				
Wyo:	Casper				
Average		5.38	5.81	5.02	4.57

Steadily increasing strontium–90 intakes since the resumption of atmospheric nuclear testing in 1961 were observed, with a peak in 1964 (table 5). The maximum intake observed for any month was 140 pCi/day in May 1963 (*9*).

Cesium–137 intakes (table 6) were seen to parallel strontium–90 intakes, reaching a peak in 1964. The maximum daily intake of 720 pCi/day was observed in February 1964.

The relationship between calcium intakes in milk and diet are given in table 7. For comparison purposes it was assumed that five cups (1.183 liters) of milk were consumed per day.

Table 4. Average daily strontium-89 intake (pCi/day), 1963

Sampling locations		1963							
		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Ala:	Tuscaloosa	290		190		205			80
Ariz:	Grand Canyon			45		45			<5
Ark:	Little Rock	110	160	220	160	195	65	105	70
Calif:	Los Angeles	40	40	35	45	20	<5	40	<40
	San Francisco	160	185	260	185	105	35	15	15
Idaho:	Boise	145				125			30
Ill:	Chicago	40	<20	20	20	110	35	70	20
La:	New Orleans	320	315	280	105	135	55	75	95
Maine:	Portland	20		<5		75			70
Minn:	Duluth	40	<20	<20	<20	180	15	215	45
Mo:	St. Louis	95		60		190			<15
Nev:	Reno	20		20		120			45
N. Y:	Buffalo	80		20		105			35
	New York	15	20	35	20	125	35	125	100
N. Dak:	Bismark	100		20		245			130
Okla:	Oklahoma City	105		105		95			65
Ore:	Portland	80	85	145	25	235	140	70	45
S. C:	Columbia	140		220		160			85
S. Dak:	Sioux Falls	35	<20	35	50	140	60	45	35
Tenn:	Knoxville	65	70	200	95	210	70	35	85
Utah:	Salt Lake City								
W. Va:	Charleston	45		150		255			100
Wyo:	Casper	55		15		70			25
Average		95	90	99	102	143	51	80	56

Table 5. Average daily strontium-90 intake (pCi/day), 1963–1964

Sampling locations		1963								1964			
		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb	Apr	May	Jun
Ala:	Tuscaloosa	39		41		66			45				
Ariz:	Grand Canyon			40		73			31				
Ark:	Little Rock	32	53	47	57	60	94	80	66				
Calif:	Los Angeles	11	14	19	23	23	22	18	12	28	26	31	19
	San Francisco	24	32	36	46	47	27	27	18				
Idaho:	Boise	19				71			36				
Ill:	Chicago	26	24	25	34	45	43	41	43	43	47	41	44
La:	New Orleans	51	69	76	51	47	83	69	65	67	82	92	85
Maine:	Portland	15		31		48			65				
Minn:	Duluth	38	44	45	38	77	57	52	62				
Mo:	St. Louis	39		40		72			66	52	42	56	67
Nev:	Reno	24		18		49			39				
N. Y:	Buffalo	26		25		52			57	50	59	46	59
	New York	17	26	27	30	49	91	71	136	55	61	56	72
N. Dak:	Bismark	31		63		110			63	84	92	101	83
Okla:	Oklahoma City	43		33		27			49				
Ore:	Portland	34	42	54	140	86	85	52	43	66	80	83	71
S. C:	Columbia	34		50		51			69				
S. Dak:	Sioux Falls	29	35	35	29	48	77	88	41				
Tenn:	Knoxville	38	28	43	66	85	100	87	92	66	66	91	97
Utah:	Salt Lake City									52	55	48	47
W. Va:	Charleston	37		38		71			56				
Wyo:	Casper	29		22		48			21				
Average		31	37	38	51	62	68	59	53	56	61	65	56

Table 6. Average daily cesium-137 intake (pCi/day), 1963–1964

Sampling locations		1963								1964			
		Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb	Apr	May	Jun
Ala:	Tuscaloosa	115		190		250			185				
Ariz:	Grand Canyon			65		45			100				
Ark:	Little Rock	85	180	180	195	240	325	370	215				
Calif:	Los Angeles	40	100	70	95	135	130	185	125	260	220	260	160
	San Francisco	45	125	160	205	280	255	310	120				
Idaho:	Boise	70				250			180				
Ill:	Chicago	115	145	150	185	260	270	290	270	280	370	320	260
La:	New Orleans	160	210	215	275	170	255		200	280	410	370	260
Maine:	Portland	65		195		330			410				
Minn:	Duluth	230	220	280	175	425	305	290	395				
Mo:	St. Louis	165		145		305			140	290	350	270	280
Nev:	Reno	80		55		210			255				
N. Y:	Buffalo	205		180		240			300	360	380	310	330
	New York	135	110	185	160	280	420	430	375	280	460	330	420
N. Dak:	Bismark	175		125		80			230	405	440	350	320
Okla:	Oklahoma City	130		140		165			115				
Ore:	Portland	125	190	220	520	430	600	325	245	720	700	700	550
S. C.:	Columbia	125		185		220			185				
S. Dak:	Sioux Falls	200	180	190	120	275	320		220				
Tenn:	Knoxville	105	120	160	155	280	360	455	235	360	410	410	390
Utah:	Salt Lake City									460	600	420	420
W. Va:	Charleston	140		150		275			195				
Wyo:	Casper	110		100		190			140				
Average		125	158	159	209	243	324	266	220	370	434	374	339

Table 7. Ratio of calcium intake from milk relative to calcium intake from diet

Station		1964			
		Feb	Apr	May	Jun
Calif:	Los Angeles	0.56	0.67	0.57	0.68
Ill:	Chicago	0.58	0.58	0.74	0.59
La:	New Orleans	0.79	0.75	0.71	0.79
Mo:	St. Louis	0.61	0.61	0.70	0.61
N. Y:	Buffalo	0.67	0.70	0.78	0.68
	New York	0.64	0.54	0.89	0.65
S. Dak:	Sioux Falls	0.64	0.67	0.70	0.88
Ore:	Portland	0.53	0.65	0.58	0.61
Tenn:	Knoxville	0.57	0.58	0.61	0.41
Utah:	Salt Lake City	0.63	0.58	0.70	0.59

Table 8 shows the relationship of strontium–90 in milk to strontium–90 in the total diet. The wide range of this ratio gives some indication that only a relative idea of the strontium–90 intake from the diet can be obtained from determinations of strontium–90 in milk alone.

Table 8. Ratio of strontium-90 intake from milk relative to strontium-90 intake from diet

Station		1964			
		Feb	Apr	May	Jun
Calif:	Los Angeles	0.25	0.46	0.29	0.32
Ill:	Chicago	0.63	0.32	0.66	0.57
La:	New Orleans	1.00	0.80	0.80	0.73
Mo:	St. Louis	0.46	0.64	0.59	0.64
N. Y:	Buffalo	0.46	0.37	0.48	0.66
	New York	0.46	0.44	0.66	0.50
S. Dak:	Sioux Falls	0.74	0.57	0.79	1.00
Ore:	Portland	0.45	0.59	0.76	0.66
Tenn:	Knoxville	0.53	0.74	0.74	0.45
Utah:	Salt Lake City	0.62	0.60	0.71	0.66

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STRONTIUM-90 IN TRI-CITY DIETS FEBRUARY–APRIL 1965 [1]

Health and Safety Laboratory
U.S. Atomic Energy Commission

Since March 1960, the Health and Safety Laboratory, through its quarterly diet study, has made estimates of the strontium–90 content of the average diet of individuals living in New York City, San Francisco, and Chicago.

Selected foods representing 19 food categories are purchased at each of these three cities about every 3 months and are analyzed for strontium–90. Fourteen of the diet categories are analyzed on a quarterly basis. Eggs, poultry, fresh fish, shellfish, and meat are purchased quarterly, but analyzed annually. This policy was initiated in 1965 due to the lower concentrations of strontium–90 in these food categories. The contribution of these five diet categories to the total annual intake of strontium–90 over the last four years has been approximately five percent. Therefore, this figure is used to calculate the contribution of these food categories to the total diet strontium–90 intake. These values are added to the contributions of the other 14 food categories to obtain quarterly estimates of annual strontium–90 intake at the three cities. Consumption figures used are based upon data from the Department of Agriculture (*1*).

Some food types are assumed to be representative of larger food categories, such as liquid milk for dairy products in general.

The consumption data are based on a weight-as-purchased basis. Before the food samples for the Tri-City Diet Study are ashed for radiochemical analysis, they are prepared to a certain degree as if for actual consumption. For example, fruits are peeled, eggs are shelled, and poultry is boned. Therefore, concentrations of radioactivity in foods as reported in the Tri-City Diet Study are based on the trimmed weight. No correction is made for the waste.

After two samplings at each city, it was found that the calcium content of most food categories did not vary among cities, nor did it vary significantly with time. Calcium analyses of dietary components were performed for the third time recently, and further confirmed this result (*2*). Calcium analyses were therefore discontinued and average calcium content of foods was computed and used to estimate the average annual intake of this material. Details of the sampling system and a discussion of the results obtained have been previously summarized (*3*).

Results of the February to April 1965 sampling are presented in table 1. The variation with time of the daily intake of strontium–90 in the three cities is plotted in figure 1.

[1] Data from Fallout Program Quarterly Summary Report (for the period June 1 through September 1) October 1, 1965, HASL–164. Available from the Clearinghouse for Federal Scientific and Technical Information, CFSTI, 5285 Port Royal Road, Springfield, Virginia 22151.

Table 1. Average dietary consumption, calcium, and strontium-90 intake for February to April 1965 sampling

Food category	Diet (kg/yr)	Calcium (g/yr)	Strontium-90 intake					
			New York City—2/65		Chicago—4/65		San Francisco—3/65	
			pCi/kg	pCi/yr	pCi/kg	pCi/yr	pCi/kg	pCi/yr
Bakery products	37	37.0	23.2±0.6	858	23.1±1.2	855	10.2±0.8	377
Whole grain products	11	10.0	39.5±0.7	434	46.6±1.4	513	23.2±1.2	255
Fresh vegetables	43	15.0	12.7±0.4	546	9.9±0.4	426	3.6±0.3	155
Root vegetables	17	6.1	13.0±0.3	221	9.9±0.4	168	8.7±0.4	148
Milk	221	234.4	18.3±0.4	4,044	15.6±0.5	3,447	15.5±0.5	3,426
Flour	43	8.6	28.3±0.3	1,217	23.2±0.5	998	6.1±0.3	262
Macaroni	3	0.7	14.9±0.4	45	18.0±0.6	54	8.9±0.4	27
Rice	3	1.1	4.1±0.3	12	5.3±0.3	16	3.3±0.2	10
Dried beans	3	2.9	20.2±0.8	61	34.9±1.9	105	16.7±1.4	50
Fresh fruit	68	12.6	5.3±0.2	360	4.1±0.3	279	3.2±0.3	218
Potatoes	45	5.8	12.0±0.5	540	7.9±0.8	356	3.9±0.3	176
Canned fruit	26	1.3	3.3±0.1	86	4.0±0.2	104	2.3±0.2	60
Fruit juices	19	1.7	4.8±0.2	91	6.8±0.3	129	5.2±0.3	99
Canned vegetables	20	4.2	13.1±0.4	262	11.8±0.5	236	2.6±0.3	52
Meat, fish, poultry, shellfish and eggs	99	42		*462		*405		*280
Annual intake		383		9,239		8,092		5,595
pCi ^{90}Sr/g Ca				24.1		21.1		14.6

* Estimated as 5 percent of total intake.

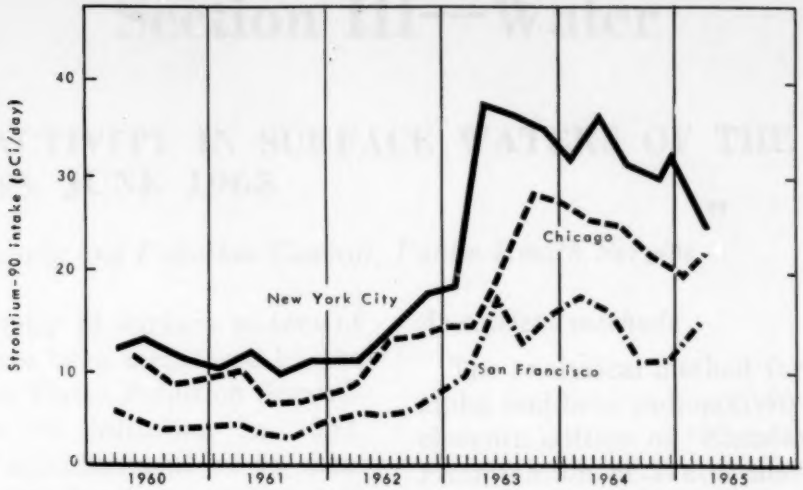

Figure 1. Daily intake of strontium–90 in New York City, Chicago, and San Francisco

Discussion

The previously noted geographic distribution pattern of strontium–90 in the diet is seen to persist as it has since the initial samplings in 1960. Levels have been highest in New York City and lowest in San Francisco. In all three cities the strontium–90 intake is observed to increase with respect to the previous sampling period 3 months earlier. This is presumed to reflect the anticipated spring rise. Due in part to its high annual consumption, milk continues to be the predominant source of strontium–90 in diet.

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(*1*) U.S. DEPARTMENT OF AGRICULTURE. Food consumption of households in the United States, Report No. 1, 1955. Household Food Consumption survey. Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (December 1956). Price $1.00.

(*2*) U.S. ATOMIC ENERGY COMMISSION. Fallout program quarterly summary report, HASL–144:281–287, Office of Technical Services, Department of Commerce, Washington, D.C. 20230 (April 1, 1964). Price $4.00. Summarized in Rad Health Data 5:285–288 (June 1964).

(*3*) RIVERA, J., and J. H. HARLEY. HASL contributions to the study of fallout in food chains, HASL–147. Office of Technical Services, Department of Commerce, Washington, D.C. 20230 (July 1, 1964). Price $1.50.

Recent coverage in *Radiological Health Data:*

Period	Issue
Sixteenth Sampling (February 1964–April 1964)	*December 1964*
Seventeenth Sampling (July–September 1964)	*March 1965*
Eighteenth Sampling (August–October 1964)	*June 1965*
Nineteenth Sampling (November 1964–January 1965)	*September 1965*

Section III—Water

GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, JUNE 1965

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been monitored by the Public Health Service Water Pollution Surveillance System since its initiation in 1957. Beginning with the establishment of 50 sampling points, this system has been expanded to include 131 stations. These stations are operated jointly with other Federal, State, and local agencies, and with private industries. Samples are taken from surface waters of all major U.S. river basins for physical, chemical, biological, and radiological analyses. The system provides background information necessary for recognizing water quality trends and for determining current and general levels of surface water contamination and early detection of specific situations which may warrant more detailed evaluation. Data assembled through the system and exact locations of sampling points are published in annual compilations (*1–8*).

Sampling procedures

The participating agencies collect 1-liter "grab" samples each week and ship them "as is" to the Surveillance System Laboratory in Cincinnati for analysis. Gross alpha and gross beta radioactivity determinations on the suspended and dissolved solids are performed as frequently as deemed necessary. Presently, gross alpha and beta determinations are made either on monthly composites of the weekly samples or on each weekly sample. Weekly alpha and beta determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are conducted at all newly established stations for the first year of operation. Weekly analyses are also scheduled for selected stations in an effort to detect short-term increases in radioactivity from current or recent nuclear tests or events.

Analytical methods

The analytical method for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*9*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred membrane filter) in an internal proportional counter. Reference sources of U_3O_8, which give a known count rate if the instrument is performing properly, are used for daily checking of the counter.

Normally, samples are counted within 2 weeks following collection or within 1 week after compositing. The decay of activity is followed for each sample for which the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the date of collection.

Results

Table 1 presents the most recent results of alpha and beta analysis of U.S. surface waters. The stations on a river are arranged in the table according to their relative locations, the first stations listed being closest to the headwaters. These data are preliminary. The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pCi/liter. When all samples have zero pCi/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5, the mean is reported as <1 pCi/liter.

Table 1. Radioactivity in raw surface waters, June 1965[a]

(Average concentrations in pCi/liter)

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex.	15	6	21	4	1	5
Apalachicola River:						
Chattahoochee, Fla.	1	4	5	0	0	0
Arkansas River:						
Coolidge, Kans.	64	312	376	12	19	31
Ponca City, Okla.	127	24	151	28	1	29
Atchafalaya River:						
Morgan City, La.	20	13	33	7	1	8
Bear River:						
Preston, Idaho	2	16	18	0	1	1
Big Horn River:						
Hardin, Mont.	85	14	99	18	3	21
Chena River:						
Fairbanks, Alaska	9	6	15	2	1	3
Clearwater River:						
Lewiston, Idaho	2	3	5	0	0	0
Clinch River:						
Clinton, Tenn.	1	3	4	0	0	0
Kingston, Tenn.	1	20	21	0	0	0
Colorado River:						
Loma, Colo.	30	11	41	9	3	12
Page, Ariz.	1	20	21	<1	5	5
Parker Dam, Calif-Ariz.	1	23	24	0	6	6
Columbia River:						
Wenatchee, Wash.	0	8	8	0	0	0
Pasco, Wash.	15	96	111	0	<1	<1
Clatskanie, Ore.	27	48	75	<1	0	<1
Connecticut River:						
Enfield Dam, Conn.	1	6	7	0	0	0
Coosa River:						
Rome, Ga.	2	4	6	1	0	1
Cumberland River:						
Cheatham Lock, Tenn.	2	8	10	1	0	1
Delaware River:						
Philadelphia, Pa.	1	7	8	0	0	0
Escambia River:						
Century, Fla.	—	—	—	—	—	—
Great Lakes:						
Duluth, Minn.	0	3	3	0	0	0
Green River:						
Dutch John, Utah	<1	18	18	0	4	4
Hudson River:						
Poughkeepsie, N.Y.	1	11	12	0	0	0
Illinois River:						
Peoria, Ill.	6	12	18	1	1	2
Grafton, Ill.	—	—	—	—	—	—
Kansas River:						
De Soto, Kans.	111	20	131	29	1	30
Klamath River:						
Keno, Ore.	1	14	15	0	0	0
Maumee River:						
Toledo, Ohio	2	12	14	1	2	3
Merrimack River:						
Lowell, Mass.	1	6	7	0	0	0
Mississippi River:						
St. Paul, Minn.	5	30	35	0	3	3
E. St. Louis, Ill.	16	17	33	3	1	4
New Roads, La.	25	14	39	7	1	8
New Orleans, La.	20	13	33	6	1	7
Missouri River:						
Williston, N. Dak.	8	15	23	1	3	4
Bismarck, N. Dak.	7	19	26	1	4	5
St. Joseph, Mo.	106	22	128	21	4	25
North Platte River:						
Henry, Nebr.	14	30	44	2	14	16
Ohio River:						
Toronto, Ohio	1	10	11	0	0	0
Huntington, W. Va.	1	10	11	0	1	1
Cairo, Ill.	2	8	10	0	0	0
Pend Oreille River:						
Albeni Falls Dam, Idaho	4	4	8	1	<1	1
Platte River:						
Plattsmouth, Nebr.	277	27	304	72	2	74
Potomac River:						
Washington, D.C.	0	7	7	0	1	1
Rainy River:						
Baudette, Minn.	3	16	19	0	0	0
Red River, North:						
Grand Forks, N. Dak.	19	34	53	4	2	6
Red River, South:						
Index, Ark.	2	21	23	0	0	0
Alexandria, La.	10	14	24	3	1	4
Rio Grande:						
Alamosa, Colo.	—	—	—	—	—	—
El Paso, Tex.	50	16	66	17	5	22
Laredo, Tex.	96	16	112	23	2	25
Brownsville, Tex.	—	—	—	—	—	—
Sacramento River:						
Greens Landing, Calif.	1	3	4	0	0	0
San Joaquin River:						
Vernalis, Calif.	3	5	8	1	1	2
San Juan River:						
Shiprock, N. Mex.	40	9	49	12	1	13
Savannah River:						
Port Wentworth, Ga.	3	8	11	<1	0	<1
Snake River:						
Payette, Idaho	2	6	8	1	1	2
Wawawai, Wash.	4	3	7	1	0	1
South Platte River:						
Julesburg, Colo.	15	58	73	2	38	40
Susquehanna River:						
Conowingo, Md.	0	5	5	0	0	0
Tennessee River:						
Chattanooga, Tenn.	1	8	9	0	0	0
Wabash River:						
New Harmony, Ind.	21	11	32	4	1	5
Yellowstone River:						
Sidney, Mont.	99	11	110	25	3	28
Maximum	277	312	376	72	38	74
Minimum	0	3	3	0	0	0

[a] These data are preliminary: reanalysis of some samples may be made and additional analyses not completed at the time of this report may become available. For final data, one should consult the system's annual report.

Dashes indicate no sample.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations as shown in figure 1, which gives the average total beta activity in suspended-plus-dissolved solids in raw water collected at each station.

It has been observed that in water the natural environmental beta activity is usually several times that of the natural environmental alpha activity. Nuclear installations may contribute additional alpha and/or beta activity whereas fallout primarily contributes additional beta activity.

The radioactivity associated with dissolved solids provides a rough indication of the levels which would occur in treated water, since nearly all suspended matter is removed by treatment processes (*10*). The Public Health Service Drinking Water Standards state that when strontium–90 and unidentified alpha emitters are a negligibly small fraction of the specific limits of 10 pCi/liter and 3 pCi/liter, respectively, a water supply is acceptable when the gross beta concentration does not exceed 1,000 pCi/liter (*11*). Table 2 indicates stations at which radioactivity was relatively high. These higher values almost always reflect high suspended or dissolved solids.

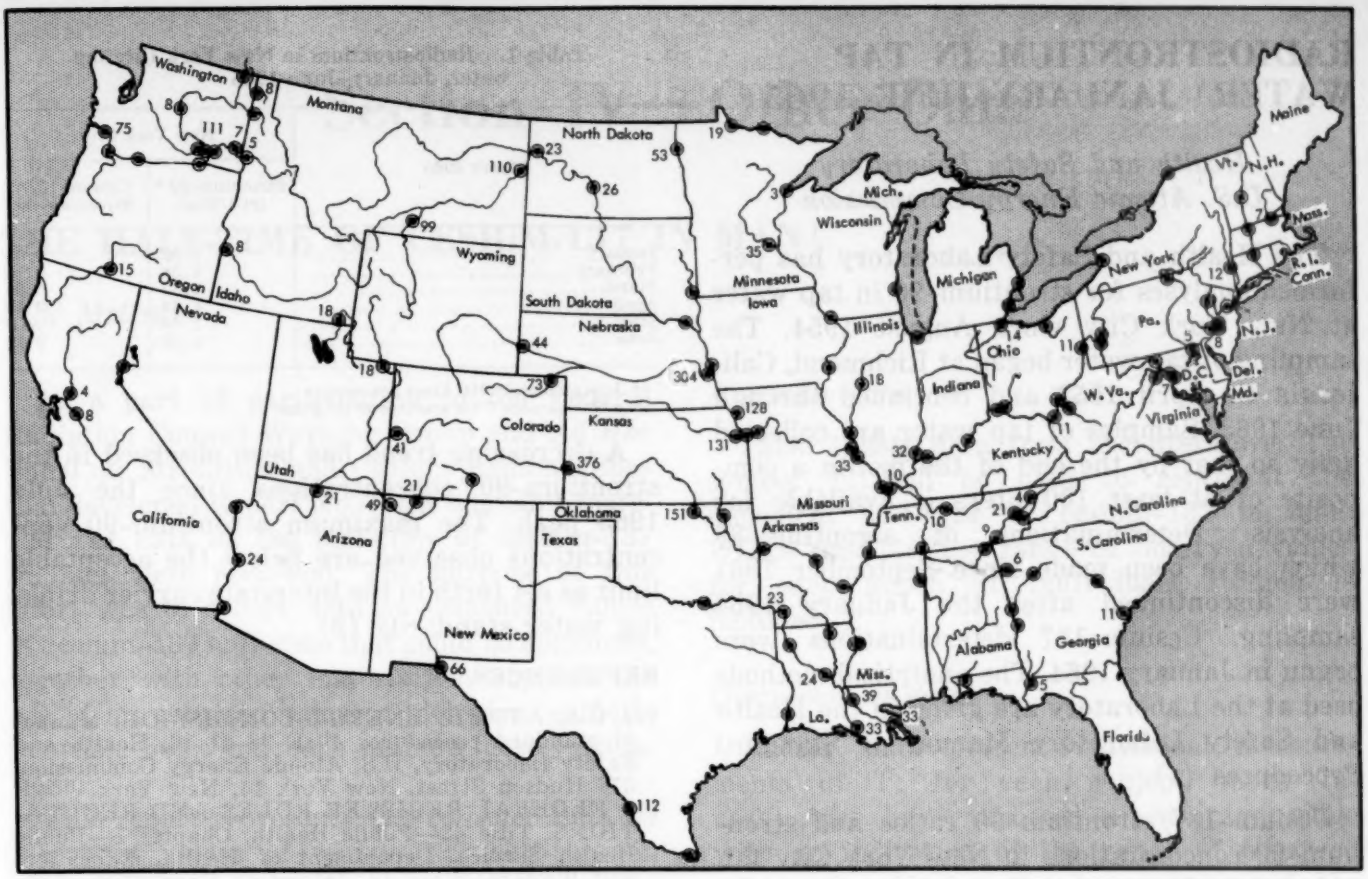

Figure 1. Sampling locations and associated total beta activity (pCi/liter) in surface waters, June 1965

Table 2. Summary, June 1965

Station	Sample activity	Remarks
Arkansas River:		
Coolidge, Kans	α, Dissolved, 19 pCi/liter.	143 mg/liter dissolved solids.
	β, Dissolved, 312 pCi/liter.	A marked reduction from May 1965.
Ponca City, Okla	α, Suspended, 28 pCi/liter.	Sample contained 1,316 mg/liter suspended solids.
Big Horn River:		
Hardin, Mont	α, Suspended, 18 pCi/liter.	Sample contained 1,208 mg/liter suspended solids.
Kansas River:		
DeSoto, Kans	α, Suspended, 29 pCi/liter.	Sample contained 1,552 mg/liter suspended solids.
Missouri River:		
St. Joseph, Mo	α, Suspended, 21 pCi/liter.	Sample contained 1,484 mg/liter suspended solids.
Platte River:		
Plattsmouth, Nebr	α, Suspended, 72 pCi/liter.	Sample contained 4,423 mg/liter suspended solids.
	β, Suspended, 277 pCi/liter.	
Rio Grande:		
El Paso, Tex	α, Suspended, 17 pCi/liter	Sample contained 539 mg/liter suspended solids.
Laredo, Tex	α, Suspended, 27 pCi/liter.	Sample contained 1,488 mg/liter suspended solids. Of five samples, four were in the normal low range of suspended solids and one collected 6/15/65 showed the only high level.
Yellowstone River:		
Sidney, Mont	α, Suspended, 25 pCi/liter.	Sample contained 1,771 mg/liter suspended solids.

REFERENCES

(*1*) DIVISION OF WATER SUPPLY AND POLLUTION CONTROL, PUBLIC HEALTH SERVICE. National water quality network annual compilation of data. PHS Publication No. 663, 1958 Edition, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price $1.50.

(*2*) *Ibid.*, 1959 Edition. Price $1.75.

(*3*) *Ibid.*, 1960 Edition.

(*4*) *Ibid.*, 1961 Edition.

(*5*) *Ibid.*, 1962 Edition.

(*6*) DIVISION OF WATER SUPPLY AND POLLUTION CONTROL, PUBLIC HEALTH SERVICE. Water pollution surveillance system, annual compilation of data. PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*7*) *Ibid.*, 1964 Edition (in preparation).

(*8*) *Ibid.*, 1965 Edition (in preparation).

(*9*) AMERICAN PUBLIC HEALTH ASSOCIATION, AMERICAN WATER WORKS ASSOCIATION, and WATER POLLUTION CONTROL FEDERATION. Standard methods for the examination of water and wastewater. 11th Edition, New York (1960).

(*10*) STRAUB, C. P., Significance of radioactivity data. JAWWA 53:704 (June 1961).

(*11*) PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962. Public Health Service Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).[1]

[1] Single free copies of this publication may be obtained from Public Inquiries Branch, Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C. 20201.

RADIOSTRONTIUM IN TAP WATER[1] JANUARY–JUNE 1965

Health and Safety Laboratory
U.S. Atomic Energy Commission

The Health and Safety Laboratory has performed analyses for strontium–90 in tap water at New York City since August 1954. The sampling of tap water began at Richmond, California in April 1958 and continued through June 1963. Samples of tap water are collected daily so that by the end of the month a composite of at least 100 liters is available for analysis. Determinations of strontium–89 which have been made since September 1961 were discontinued after the January 1964 sampling. Cesium–137 determinations were begun in January 1964. The analytical methods used at the Laboratory are given in the Health and Safety Laboratory Manual of Standard Procedures (*1*).

Cesium–137/strontium–90 ratios and strontium–90 concentrations in New York City tap water for January through June 1965 are presented in table 1. Strontium–90 concentrations appear graphically in figure 1.

[1] Prepared from information appearing in Fallout Program Quarterly Summary Report, HASL–164. This report is available from the Clearinghouse for Federal Scientific and Technical Information, CFSTI, 5285 Port Royal Road, Springfield, Virginia 22151. Price $7.00.

Table 1. Radiostrontium in New York City tap water, January–June 1965

Month 1965	New York City	
	Strontium-90 [a] (pCi/liter)	Cesium-137/ Strontium-90
January	1.62	0.08
February	1.58	0.10
March	1.32	0.09
April	1.64	0.13
May	1.34	[b] AIP
June	1.73	0.12

[a] Approximately 100 liters per sample
[b] AIP indicates ^{137}Cs analysis in progress.

A decreasing trend has been observed in the strontium–90 concentrations since the July 1963 peak. The maximum strontium–90 concentrations observed are below the acceptable limit as set forth in the interstate carrier drinking water standards (*2*).

REFERENCES

(*1*) U.S. ATOMIC ENERGY COMMISSION. Manual of standard procedures 40:E–38–01–16, Health and Safety Laboratory, U.S. Atomic Energy Commission, 376 Hudson Street, New York 14, New York.

(*2*) FEDERAL REGISTER RULES AND REGULATIONS. Title 42—Public Health, Chapter 1—Public Health Service, Department of Health, Education, and Welfare; Part 72, Interstate Quarantine, Subpart J, Drinking Water Standards, 27:2154–2155, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402 (March 6, 1962).

Recent coverage in *Radiological Health Data:*

Period	Issue
January–April 1962	*September 1962*
March–June 1962	*January 1963*
July–December 1962	*July 1963*
January–April 1963	*January 1964*
May–October 1963	*April 1964*
November 1963–December 1964	*June 1965*

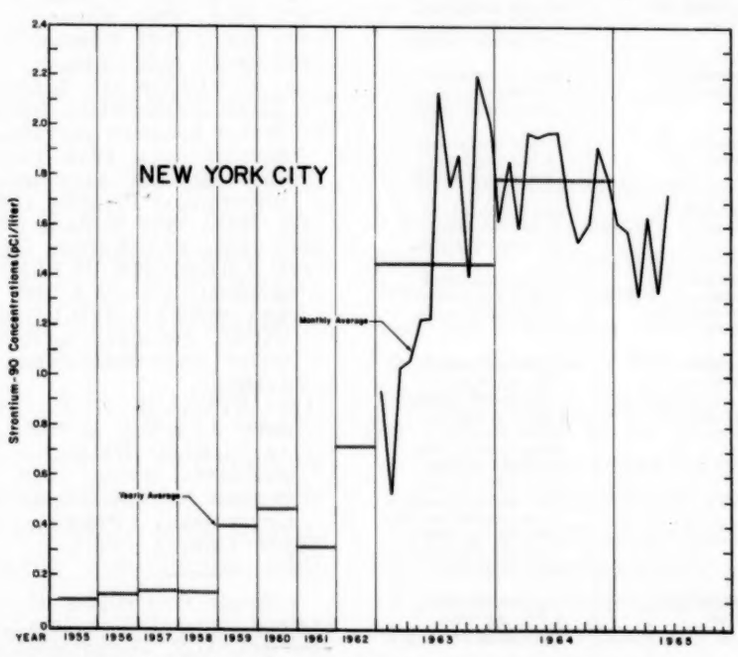

Figure 1. Strontium–90 concentrations in New York City tap water

Section IV—Other Data

THE HALF-TIME OF CESIUM-137 IN MAN[1]

T. F. McCraw[2]

As a part of participation in the Federal Radiation Council Working Group and *Ad Hoc* Panel on Strontium and Cesium Radionuclides that developed Report No. 7, the available material and data on the half-time of cesium–137 in man were reviewed. The purpose of this effort was to collect data on measured values of cesium–137 half-time that could be employed, together with other material, to support the use of an assumed value of biological half-life in whole body and bone marrow dose calculations.

This report represents (1) collected data on measured values of cesium–137 half-time in man, (2) a suggested model for expressing cesium–137 half-time as a function of age, and (3) estimates of doses and body burdens for a given intake of cesium–137 and for intake of cesium–137 in milk, using an assumed pattern of milk consumption by various ages.

One important consideration in determining whole body and bone marrow radiation dose to an exposed population from internal cesium–137 is the effective half-time of this radionuclide in man. Should there be a different biological half-time for cesium–137 in various age groups within a population and an effective half-time[3] which varies as a function of age, it will be necessary to consider this factor in determining doses to the population and in determining which age group in the population will receive the highest exposure from a contaminating event.

[1] Adapted from HASL–164:281–300, Clearinghouse for Federal Scientific and Technical Information, 5285 Port Royal Road, Springfield, Virginia 22151 (October 1, 1965). Price $7.00.

[2] Mr. McCraw is a Health Physicist with the Division of Operational Safety, Atomic Energy Commission, Germantown, Maryland.

[3] For cesium–137 in man, the radiological half-time is so long (about 11,000 days) and the biological half-time is so short (of the order of 100 days or less) that for purposes of this report, the effective half-time can be considered equal to the biological half-time.

Available data

Table 1 lists data from the literature. The symbol T_b will be used to represent the biological half-time of cesium–137 in man. Where possible, the range of observed values for each group of individuals studied is included.

Discussion of data

Rather than present individual measurements of T_b for each subject, many investigators have reported an average value with an indication of the range of observed values. Considering the lower limits of the range of values for "adults" (unweighted for number of subjects) for all investigators where a range was given, the average value for the lower limits is about 78 days. The average value for the upper limits is about 122 days, and the overall average is about 98 days for these data.

The unweighted mean of the "Body Radioactivity Measurements and Excretion or Dietary Analysis" data from Rundo's summary is 110 days. The "Body Radioactivity Measurements" give an unweighted mean of 108 days. The "Excretion or Dietary Analysis" data give an unweighted mean of 114 days. Thus, the two techniques appear to give results which are in close agreement.

The data collected on T_b for groups of subjects are presented graphically in figure 1. Also plotted are individual values for 6- and 8-year-old girls and for two infants (Rundo), and values for three young women and two infants (Bengtsson *et al.*). In order to display the data for "adults", it has been assumed that this age group consists of those about 20 to 25 years of age and older, and the elderly are assumed to be over 60 years of age.

Table 1. Cesium-137 half-time data from the literature

Group	Age (years)	T_b (days)	Range (days)[a]	Reference
1 girl	6	34	—	(1)
1 girl	8	39	—	(1)
children	<16	50	—	(1)
limited data	all ages	105	std. deviation 35%	(1)
small group	adults	74	—	(2)
9	18–22	68	—	(2)
50 men	16–75	64	±10	(2)
33 women	17–76	65.5	±10	(2)
17 boys	10–14	44	+10 −5	(2)
Eskimos	adults	100	—	(3)
20 males	30–40	81	48 in summer 119 in winter	(4)
4 children	8–15	½ the value for adults.	—	(4)
Marshallese people		70	—	(5)
10	normal subjects	[b] 1	0.8–1.2	(6)
		[c] 89	58–129	(6)
4	men	—	109–149	(6)
1	adult	53 (in 1959) 55 (in 1961)		(6)
1	adult	94	—	(6)
1	adult	136	—	(6)
average value		110	—	(7)
average value		140	—	(8)
2	adults	[d] 110	—	(9)
3	adults	[d] 115	110–119	(9)
1	adult	[d] 74	—	(9)
1	adult	[d] 144	—	(9)
2	adults	[d] 60	57–63	(9)
4	adults	[d] 135	110–147	(9)
1	adult	[d] 150	—	(9)
4	adults	[d] 122	109–148	(9)
5	adults	[d] 75	54–114	(9)
4	adults	[d] 109	79–123	(9)
10	adults	[d] 89	58–129	(9)
6	adults	[e] 145	—	(9)
2	adults	[e] 125	92–157	(9)
1	adult	[e] 188	—	(9)
91	adults	[e] 110	—	(9)
2	adults	[e] 56	53–60	(9)
5	adults	[e] 98	86–112	(9)
2	adults	[e] 170	140–200	(9)
3	adults	[e] 97	53–140	(9)
1	adult	[e] 71	—	(9)
10	adults	[e] 76	—	(9)
3	adults	99	76–126	(10)
1	adult	81	—	(11)
1	adult	95	—	(11)
1 woman-IS	22	69	±4	(12)
		65	[f] ±5	(12)
1 woman	26	73	±10	(12)
1 woman-EB	23	32	±2	(12)
1 infant of IS	12 days	21	±5	(12)
1 infant of EB	2 days	25	±3	(12)
1 infant	early infancy	9.6	—	(13)
1 infant	early infancy	6.6	—	(13)
12	adults	91	±18	(14)
1 infant	17 days	13	—	(15)
1 infant	24 days	33	—	(15)
1 infant	36 days	21	—	(15)
1 infant	86 days	18	—	(15)
1 infant	143 days	12	—	(15)
1 child	5	29	—	(15)
1 child	5	43	—	(15)
1 child	9	40	—	(15)
1 adult	21	108	—	(15)
1 adult	23	100	—	(15)
1 adult	24	77	—	(15)
1 adult	31	76	—	(15)
1 adult	33	101	—	(15)
1 adult	33	121	—	(15)
1 adult	35	131	—	(15)
1 adult	33	94	—	(15)
1 adult	35	108	—	(15)
1 adult	46	84	—	(15)
1 adult	49	136	—	(15)
1 adult	51	73	—	(15)
1 adult	52	101	—	(15)
3	elderly women	[g] 3.3	±2.0	(16)
		[h] 57	±17	(16)
2	elderly men	[g] 2.2	±1.4	(16)
		[h] 69	±16	(16)

[a] The uncertainty in the measurement is given, when available, where data are presented for one subject.
[b] Small fraction eliminated
[c] Major fraction eliminated
[d] Body radioactivity measurement
[e] Excretion or dietary analysis
[f] Ten months later
[g] Fast component
[h] Slow component

From table 1 and from figure 1, it is seen that much of the data on T_b are for "adults",

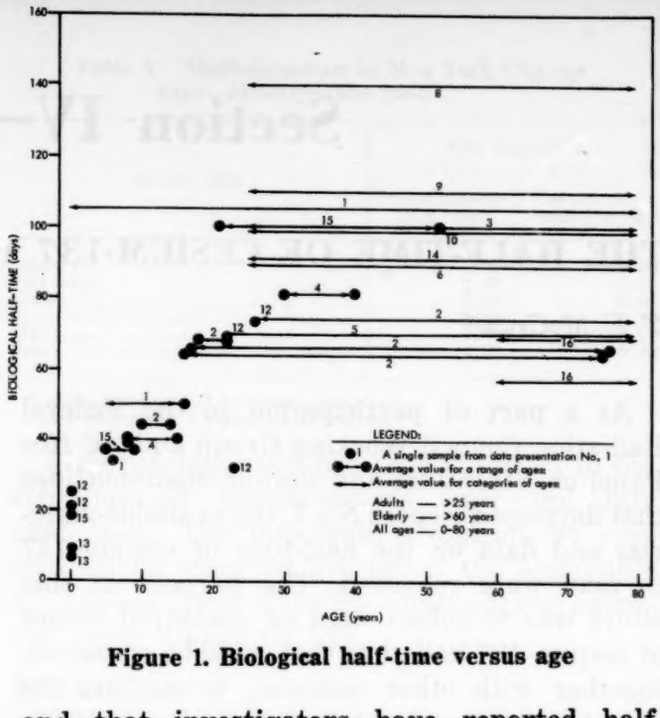
BIOLOGICAL HALF-TIME (days)
AGE (years)
LEGEND:
A single sample from data presentation No. 1
Average value for a range of ages
Average value for categories of ages
Adults — >25 years
Elderly — >60 years
All ages — 0–80 years

Figure 1. Biological half-time versus age

and that investigators have reported half-times, for adult groups, of about one day for a small fraction of the cesium–137 intake (about 10 percent) and values between about 60 and 180 days for the major portion of the intake. While part of the difference in values from various investigators may lie in the realm of factors of instrumentation, calibration, laboratory technique, etc., the measured values generally appear to represent real differences among individuals. The range of values obtained by a single investigator for a group of subjects must involve many biological and environmental factors for which there is little information. No attempt will be made to identify these factors except for the possible influence of age on the biological half-time of cesium–137 in man (age may be an indirect factor).

The data are meager, but figure 1 suggests that the value of T_b for those groups under about 20 to 25 years of age decreases with age, and that T_b may be as low as 6 to 7 days for infants a few days old. For the four infants in figure 1, the average value is about 15 days, which agrees with Pendleton's average of 19 days for five infants.

One additional feature in the data is possibly significant. For the age groups reported, no investigator (from the available reports) has reported a value of T_b greater than 70 days for *groups* under 25 years of age or a value less than about 50 to 60 days for *groups* over 25 years of age.

Guarded statements by some investigators indicate reservation in specifying trends in the data, such as relationships between T_b and age, sex, or species. Rundo has said, "If there is a change of half-life with age then it presumably starts at birth and increases steadily until adulthood is reached" (*1*). Other investigators indicate a stronger support for a relationship between T_b and age. Bengtsson *et al.* state "The results also confirm that biological half-time for cesium increases with age" (*12*). Onstead *et al.* report that in their studies involving more than 6,000 individuals, " . . . our findings suggest that, within a single species, biological half-life is dependent on age" (*17*).

In referencing the use of 100 days for the biological half-life of cesium in man, the December 1964 report to the Federal Radiation Council by the National Academy of Sciences Advisory Committee, entitled "Implications to Man of Irradiation by Internally Deposited Strontium–89, Strontium–90, and Cesium–137" (*18*) contains the following:

> "This value is almost certainly too large for children, perhaps by a factor of three to five."

The Federal Radiation Council, in its Report No. 7, (*19*) stated:

> "The data for persons younger than 25 years suggest that the biological half-life before maturity may be a function of age. Biological half-lives of about 20 days or less have been reported for infants. For this report a value of 30 days is used as the biological half-life of cesium–137 in infants."

A value of 30 days for infants appears to be a conservative assumption since the available data for infants show values close to, but below, this value.

Boni's value of 81 days, which is applicable for adults 30 to 40 years of age, is in close agreement with the average value of the lower limit for adults for all investigators of 78 days. However, there are little data for ages within the category specified as "adults" to determine if there is a trend of change in T_b as a function of age above about 25 years. The average value for adults for all investigators, those that specified a range of values and those that did not, is 101 days. The most data for an early study for all ages in a population group are for the Marshallese people, with a value of 70 days reported (*5*).

The data of Miettinen suggest an average value of about 70 days for the ages 16 through 75 years. Lists of "age limits" indicate most of these individuals were less than 50 years of age. Whether the inclusion of individuals of ages down to 16 years has the effect of lowering the average value of T_b for these groups compared to data on groups of "adults" presented by Rundo and Hansen and others, is not known. Possibly other biological and environmental factors are more important.

Model development

Considering the available values of T_b for the entire range of ages in the population, the trend that is suggested for T_b and age may be presented graphically. The solid line in figure 2 is drawn to account for the apparent rapid change of T_b with age for those less than about 25 years of age, to provide an average value of about 80 days for younger adults as suggested by Boni's measurements, and to provide an average value for adults over 25 years of age of about 100 days. Considering all age groups, the solid line in figure 2 develops an average T_b for all ages of about 75 days.

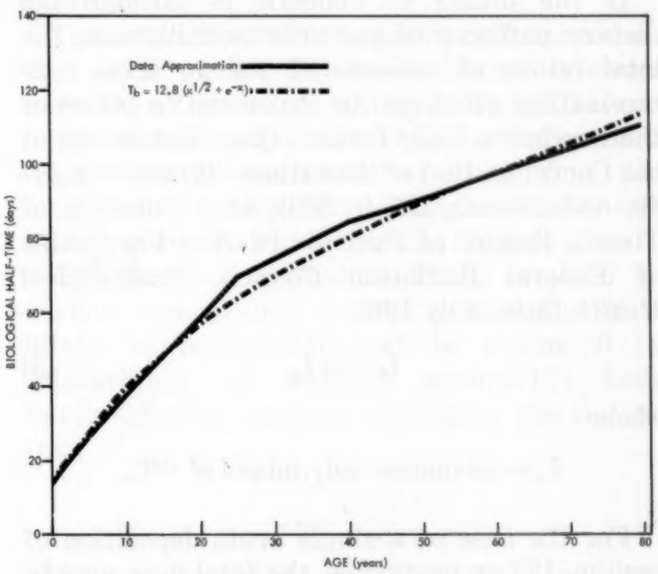

Figure 2. Biological half-time versus age

The three segments of figure 2 may be approximated by:

$$T_b = 12.8\,(x^{\frac{1}{2}} + e^{-x}) \qquad (1)$$

where:

T_b = biological half life (years)
x = age (years)

The dotted curve in figure 2 shows that the fit is good for all ages. While this expression does not provide for estimating effective half-times of cesium–137 for individuals, it does provide a close approximation to averages of measured values of cesium–137 retention for groups of subjects.

Equation (1) may be combined with the equation in FRC Report No. 7 (*19*) that relates dose to whole body and bone marrow in rads to intake of cesium–137 to form a generalized expression that includes the age of various groups within an exposed population:

$$D = \frac{I_t}{W} \times 0.03 \times 1.44 \left[12.8 \left(x^{\frac{1}{2}} + e^{-x}\right)\right]$$

$$D = \frac{0.55\ I_t\ \left(x^{\frac{1}{2}} + e^{-x}\right)}{W} \qquad (2)$$

where:

D = total dose (rads)
I_t = total intake of ^{137}Cs (microcuries)
W = body weight (kilograms)
x = age of exposed group (years)

This equation applies where it can be assumed that body weight, W, does not change significantly during exposure.

If the intake of concern is through the dietary pathway of pasture-cow-milk-man, the total intake of cesium–137 for an acute contaminating event can be expressed in terms of the maximum daily intake. (See "Estimates of the Concentration of Strontium–89, Strontium–90, and Cesium–137 in Milk as a Function of Time", Report of Special *Ad Hoc* Committee of Federal Radiation Council, *Radiological Health Data*, July 1965.

$$I_t \sim 32\ I_m \qquad (3)$$

where:

I_m = maximum daily intake of ^{137}Cs

For the case of a single acute deposition of cesium–137 on pasturage, the total dose may be estimated from:

$$D = \frac{17.6\ I_m\ \left(x^{\frac{1}{2}} + e^{-x}\right)}{W} \qquad (4)$$

For those less than about 10 years of age, most of this dose will have been received within about 1 year.

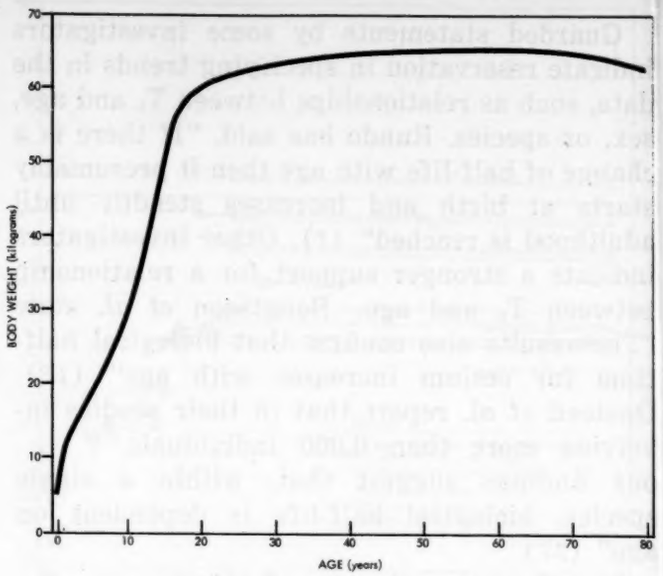

Figure 3. Body weight versus age (average for male and female)

Model application—dose estimates

Figure 3 gives the average male and female body weights in kilograms from birth to 80 years. The average values of body weight for various ages are generally not the same for male and female; however, the differences in weight are not large. For these body weights and using the generalized expression for dose, figure 4 presents the total whole body and bone marrow dose as a function of age for a total intake of 1.0 microcurie of cesium–137. The doses in figure 4 would also be obtained using equation (4) and a maximum daily cesium–137 intake in milk of $^1/_{32}$ microcurie or 31 nanocuries from an acute deposition of cesium–137.

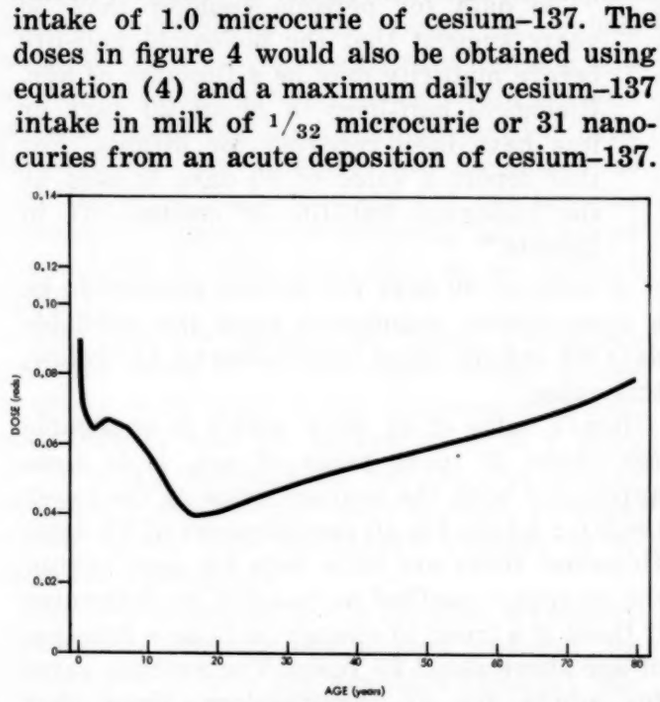

Figure 4. Total whole body and bone marrow dose from internal cesium–137 versus age (an assumed total intake of 1 μCi ^{137}Cs)

Figure 4 indicates that with the use of this model for biological half-time, the highest and lowest doses for all ages from a given intake of cesium–137 differ by a factor of about two. This occurs even though body weights vary by a factor of about 20, and biological half-times vary by a factor of about 10. For the younger ages, those less than 1 year of age receive the highest dose. Those 70 to 80 years of age may receive a comparable dose. However, definitive data for ages greater than 50 are not available and the model suggested may not be really representative for ages over 50 years.

Again, if one assumes that the dietary item of interest is whole milk, the doses in figure 4 can be modified by a pattern of intake for milk. Table 2 presents data on average at-home milk consumption as a function of age. Values of average consumption in table 2 were developed from a percentage distribution of milk intake by age (*Radiological Health Data,* January 1963). This study of at-home milk consumption was conducted throughout the United States in July 1962. Since the study did not include consumption of whole milk outside the home, consumption may be underestimated for those ages consuming whole milk away from home. Table 2 also presents the average consumption by each age group relative to consumption by males less than 1 year of age (the intake normalization factor). The average consumption for males less than one year of age is seen to be 17.8 ounces per day. This is approximately one-half liter per day (16.9 oz/day).

Table 2. Average daily fresh whole milk consumption at home in U.S.[a]

Age (years)	Average consumption (fluid ounces)		No consumption (percent)	Normalization factor consumption/<1 year male consumption	
	Male	Female		Male	Female
<1	17.8	16.3	38.0	1.0	.92
1–4	17.8	16.9	15.9	1.0	.95
5–9	16.6	14.5	20.5	.93	.81
10–14	16.9	12.7	25.0	.95	.72
15–19	16.3	10.2	28.9	.92	.58
20–24	11.8	7.5	35.1	.66	.42
25–29	9.8	6.8	39.1	.55	.38
30–34	8.7	5.7	37.5	.49	.32
35–44	8.3	5.7	39.1	.47	.32
45–54	7.6	5.4	42.0	.43	.31
55–64	8.1	5.9	40.9	.45	.33
>65	8.6	6.8	35.4	.48	.38

[a] Average consumption values and normalization factors developed from report on "National Food Consumption Survey" in Radiological Health Data, Vol IV, No. 1, January 1963.

The doses in figure 4, averaged for each age group, have been modified by the normalization factors in table 2 to illustrate the effects that a pattern of milk consumption may have on dose. The results are shown in figure 5.

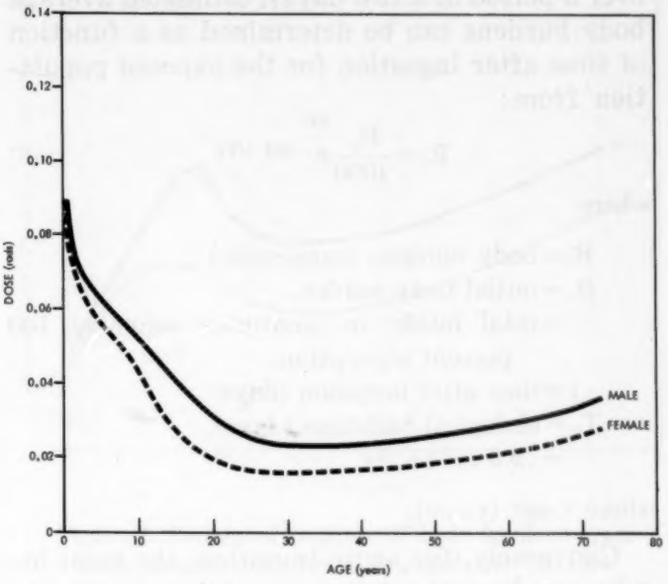

Figure 5. Total whole body and bone marrow dose from internal cesium–137 versus age (an assumed pattern of dietary intake of cesium–137 in milk for males less than 1 year of age consuming 1 μCi)

The influence of the pattern of milk consumption in table 2 is to reduce the average doses for most ages relative to the doses in figure 4.

The sex-related differences in milk consumption cause males to receive higher average doses than females for all ages. The difference in dose between ages receiving the highest and lowest values is a factor of about four for male and about five for female, and males less than 1 year of age receive the highest dose.

The yearly dose that would be received by various age *groups* from a continuing daily intake of cesium–137 may be estimated by determining the average cesium–137 body burden during the year and using the following:

$$D_r = \frac{B/W}{85.7} \qquad (5)$$

where:

D_r = dose rate (rads per year)
B = average body burden (nanocuries)
and W = body weight (kilograms)

The determination of average body burden for a continuing intake of cesium–137 is described in the following section (see equation (9) and figure 7).

Model application—body burden estimates

For acute ingestion of cesium–137 (ingestion over a period of a few days), estimated average body burdens can be determined as a function of time after ingestion for the exposed population from:

$$B_t = \frac{B_o}{1000} e^{-.693\ t/Tb} \qquad (6)$$

where

B_t = body burdens (nanocuries)
B_o = initial body burden,
= total intake in picocuries assuming 100 percent absorption,
t = time after ingestion (days),
T_b = biological half-time (days),
$= 12.8\ (x^{\frac{1}{3}} + e^{-x})$

where x age (years).

Conversely, for acute ingestion, the total intake can be estimated for various age groups if their average body burdens are known at some time after ingestion.

For ingestion of cesium–137 that decreases with time, average body burdens within the population may be estimated as a function of time from:

$$B_t = \frac{R_o}{1000\ (\lambda_i - \lambda_b)} (e^{-\lambda bt} - e^{-\lambda it}) \qquad (7)$$

where

R_o = initial rate of intake (picocuries per day),
λ_b = biological decay constant
$= .693/12.8(x^{\frac{1}{3}} + e^{-x})$,
λ_i = intake decay constant $= .693/T_i$,
T_i = half-time for intake after maximum concentration (days)

FRC Report No. 7 (*19*) indicates that for an acute deposition on pasturage, the total cesium–137 intake from milk may be 32 times the intake on the day of the maximum concentration in milk (assuming the same amount of milk is consumed each day). The portion of the total intake occurring prior to maximum concentration is about 16 percent of the total intake. The intake occurring after maximum concentration is about 27 times the maximum. Therefore, 27 days may be considered the mean time of cesium-137 in milk following maximum concentration. The half-time for intake after maximum concentration is:

$$T_i = 27 \times 0.693 \sim 18 \text{ days.}$$

For acute deposition of cesium–137 on pasturage utilized by dairy cows, it has been estimated that the maximum concentration in milk will occur about 6 days following deposition. The average body burden for various ages resulting from such changing levels in milk may be approximated by:

1. Assuming total milk intake prior to maximum concentration is an acute intake using equation (6).
2. Assuming an additional intake using the maximum daily intake as R_o in equation (7).

The estimated body burden from milk consumption will be the burden from equation (6), plus the burden from equation (7). Contributions to total body burden from other contaminated foods will be additive. Figure 6 presents the body burden for males 1 year of age, for an acute deposition on pasturage, where the maximum concentration of cesium-137 in milk reached a level of 2,000 pCi/liter. Figure 6 indicates that maximum burden will be reached in about 25 days for this age group.

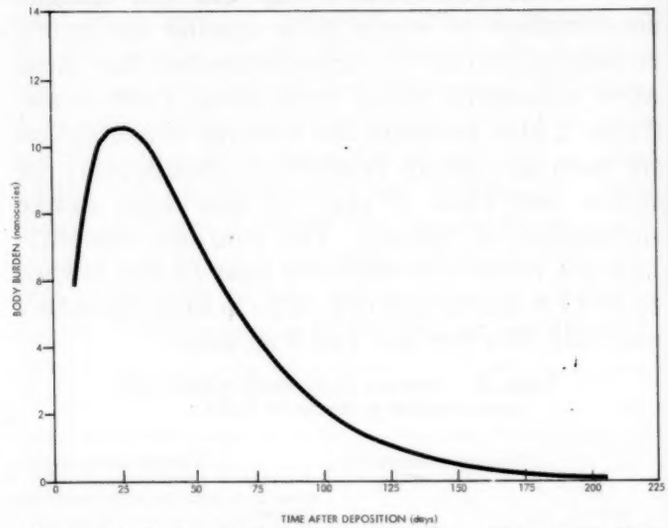

Figure 6. Cesium–137 body burden for males less than 1 year of age versus time after acute deposition (assuming maximum milk concentration reaches 2,000 pCi/liter)

Other assumptions regarding the pattern of milk consumption versus age may apply for various portions of the U.S. population. Body burdens for the milk consumption pattern in table 1 may be underestimated for the ages consuming quantities of milk away from home.

For a continuing intake of cesium–137 (intake that occurs over a period of years), estimates of average body burdens within a population can be developed from the following:

$$B = R\ T_m\ A_f/1000 \qquad (8)$$

where:

B = body burden (nanocuries)
R = rate of intake of ^{137}Cs (picocuries per day)
T_m = biological mean time (days),
A_f = absorption factor, assumed to be 1.0.

With biological mean time expressed as a function of age, equation (8) becomes:

$$B = 0.018\ R\ (x^3 + e^{-x}) \qquad (9)$$

where:

x = age (years)

Equation (9) may be used, for example, to estimate the average body burdens of cesium–137 in the U.S. population from milk consumption. The U.S. Public Health Service pasteurized milk network results for 1963 and 1964 averaged 114 and 109 pCi/liter, respectively (*20*, *21*).

These data indicate that the average level of cesium–137 in U.S. milk supplies has decreased slowly over the past 2 years. Considering the small change in these levels, it can be assumed that the various age groups in the population are in equilibrium with the cesium–137 levels in milk they consume for the portion of their body burden due to milk intake, and their average body burdens for 1964 may be determined from an average value of daily cesium–137 intake.

If it is assumed that milk ingestion for males less than 1 year of age resulted in an average intake of 55 pCi/day during 1964, and using the normalization factors in table 2 to estimate milk consumption by other age groups in the population, estimated body burdens may be determined from equation (9). The resulting values are shown in figure 7.

The dose to males less than 1 year of age from at-home milk consumption, using equation (5), is about 0.002 rad or 2.0 millirads in 1964. The point should be stressed that these estimates apply only to that portion of the cesium–137 body burdens of the U.S. population due to milk consumption at home. The contribution to body burden and whole body dose from milk consumption outside the home and from other items of the diet are additive.

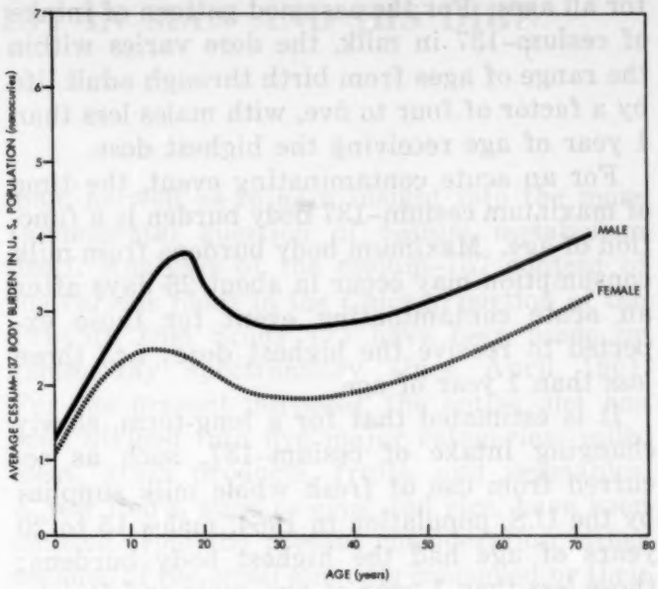

Figure 7. Estimated cesium–137 body burdens from milk consumption for U.S. population in 1964

For cesium-137 in U.S. milk supplies, estimates of cesium–137 body burden in figure 7 indicate that males 15 to 20 years of age had the highest levels; those less than 1 year of age, male and female, had the lowest levels; and females of all ages had a lower average level than males of the same age.

Summary

The observations of biological half-time for cesium–137 in man indicate that half-time is a function of age. The average biological half-times for cesium–137 from birth through adult life vary by a factor of about 10. A simple mathematical expression has been presented which relates half-time of retention of cesium–137 and age. Though the model is crude, it has utility in predictions of doses and body burdens from cesium–137 for various ages within an exposed population. Additional measurements of cesium–137 retention are needed, particularly for younger age groups, to further refine the model and to improve prediction capability. More data are also needed for the elderly.

The combination of changes in half-time and body weight results in a dose variation, for a given cesium–137 intake, from birth through adult life, of a factor of about two. The addition of assumptions regarding patterns of milk intake as a function of age and resultant cesium–137 intake leads to a different distribution of dose with age than is found for a fixed intake

for all ages. For the assumed pattern of intake of cesium–137 in milk, the dose varies within the range of ages from birth through adult life by a factor of four to five, with males less than 1 year of age receiving the highest dose.

For an acute contaminating event, the time of maximum cesium–137 body burden is a function of age. Maximum body burdens from milk consumption may occur in about 25 days after an acute contaminating event for those expected to receive the highest dose; *i.e.*, those less than 1 year of age.

It is estimated that for a long-term, slowly changing intake of cesium–137, such as occurred from use of fresh whole milk supplies by the U.S. population in 1964, males 15 to 20 years of age had the highest body burdens; those less than 1 year of age, male and female, had the lowest body burdens; and females of all ages had lower body burdens than males of the same age.

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THE RELATION BETWEEN CESIUM-137 IN MAN AND HIS DIET IN THE CHICAGO AREA [1]

Philip F. Gustafson [2]

Because of the relatively short biological half-life of cesium–137 in man (approximately 100 days for adults), changes in the cesium–137 content of the diet lead fairly rapidly to corresponding changes in the human burden of cesium–137. As a consequence, equilibrium or near-equilibrium between diet and body burden (*i.e.*, daily cesium–137 intake = daily cesium–137 elimination) can be attained within a few months. Variations in the rate and intensity of nuclear testing produce changes in the deposition of cesium–137 and its uptake by plants, which in turn cause the cesium–137 body burden of man to vary correspondingly. A period of maximal concentration of cesium-137 in foods should be followed relatively soon by maximal body burdens of this radionuclide. This is in contrast to strontium–90, the long biological half-life of which does not permit maximum concentrations in the body to be reached for a considerable time after maximum levels appear in the diet.

The relation between the cesium–137 content of the Chicago diet and the body burdens of cesium–137 in a number of Argonne employees has been examined in the hope of providing a reliable means of predicting future levels in man, as well as to gain insight into the more fundamental question of cesium metabolism itself. Analyses of the cesium–137 content of the various foods in the Chicago portion of the Tri-City Diet Study (*1*) have been made by gamma-ray spectrometry since April 1961. For the present purposes, the entire diet has been divided into five major categories: milk, meat, grain products, fruits, and vegetables. A few items, such as eggs and rice, have been omitted from the present consideration either because of the small amounts consumed or their low cesium–137 content. Fish has been excluded because of the relatively small amounts consumed and the extreme variability caused by the presence or absence of freshwater varieties which contain relatively high concentrations of cesium–137 (*2*).

The daily intake of cesium–137, in pCi/day, coming from each of the five diet categories during each quarter extending from April 1961 through July 1965 is shown in figure 1. In general, milk, meat, and grain products provided most of the cesium–137 intake. Maximum levels in the five categories, and hence in the total intake, were reached in late 1963 and early 1964, and have diminished rather consistently since that time. Also indicated in figure 1 is an attempt to extrapolate future levels on the basis of trends observed through July 1965. These extrapolated levels will be used subsequently to determine total daily intake and resultant body burdens.

[1] Taken from HASL–164:301–311 (October 1, 1965). This work was supported by the U.S. Atomic Energy Commission.

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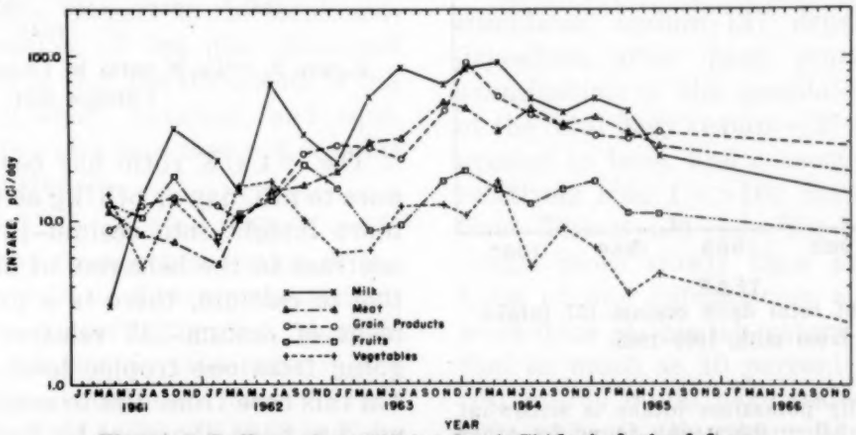
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10.0
1.0
INTAKE, pCi/day
Milk
Meat
Grain Products
Fruits
Vegetables
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1961
1962
1963
1964
1965
1966
YEAR

Figure 1. Daily cesium–137 intake (pCi/day) derived from five food categories

The percentage of cesium–137 in the total diet derived from milk is illustrated in figure 2. The supposition is often made that milk contributes on the order of 60 percent of the daily cesium–137 intake. The data in figure 2 indicate 35 to 40 percent of the total daily intake in the Chicago area comes from milk, and further suggest that the current importance of milk relative to the total diet cesium–137 is decreasing. All five categories show primary dependence upon the rate of cesium–137 deposition, rather than upon total accumulation of the radionuclide on the ground. This is inferred from the observed decrease in cesium–137 concentration in foods from 1964 through the present, even though present levels in soil are as high as, if not higher than, those in 1963. Fresh milk, fruits, and vegetables show this most clearly even though inclusion of canned and frozen items increases the time between production and consumption. The fact that cesium–137 concentration in grain products appears to be decreasing more slowly may reflect the effect of storage of this commodity, as grain grown in 1963 may not reach the consumer until 1965. Considerable grain is used for animal feed, and as such constitutes an important source of cesium–137 in beef and pork, the cesium–137 contents of which may also diminish more slowly. The effect of grain storage for unknown periods of time creates an uncertainty in the prediction of future diet levels in man by extrapolation of current observations.

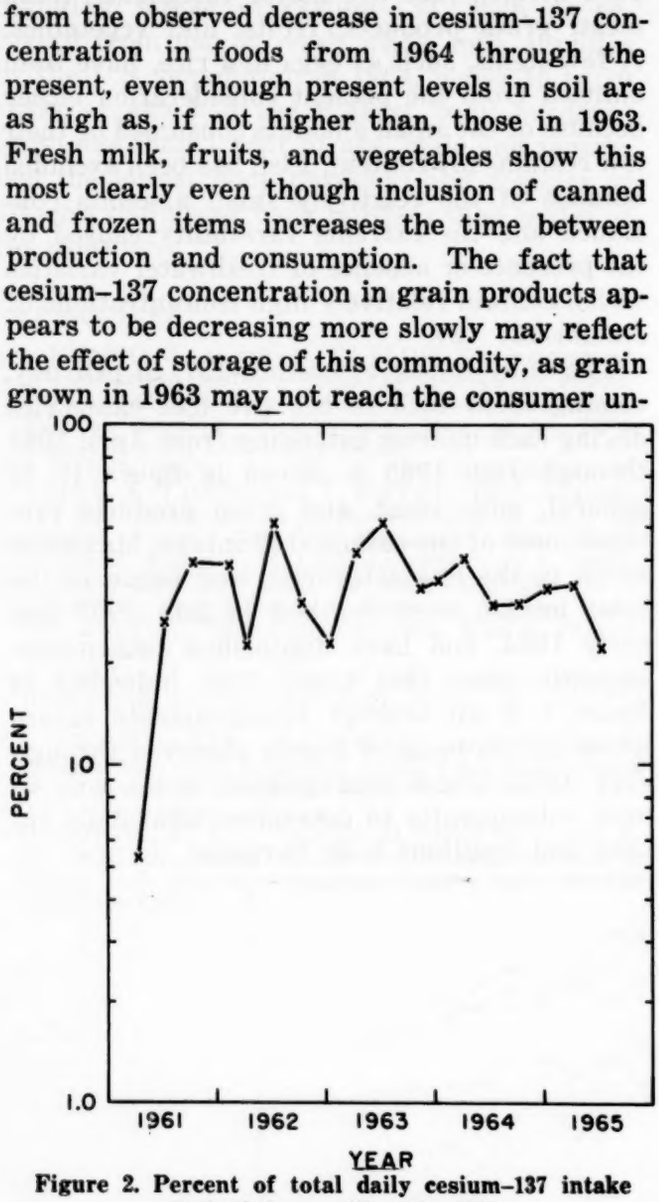

Figure 2. Percent of total daily cesium–137 intake derived from milk, 1961–1965

The daily intake of cesium–137, expressed in pCi ^{137}Cs/g K, determined from April 1961 through July 1965, is shown in figure 3. Values extending beyond July 1965, also plotted in figure 3, were obtained from extrapolation of the data in figure 1. The potassium value used in deriving these ratios was 4.5 g/day contained in 1.85 kg of food. A figure of 4.5 ± 0.3g potassium/day was the average found during 1962 through 1964.[3] The average ^{137}Cs/K ratios in man (*in vivo* ratios) observed during this time by Miller are also shown in figure 3 (*5, 6*).

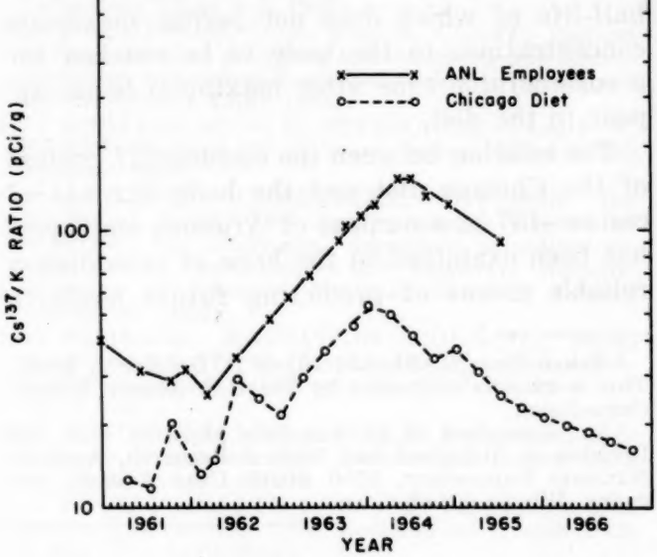

Figure 3. ^{137}Cs/K ratio in Chicago residents and Chicago diet

The ^{137}Cs/K ratio has been used in preference to pCi/day or pCi/kg as it appears to yield more insight into cesium–137 metabolism. In contrast to the behavior of strontium–90 relative to calcium, there is a pronounced enrichment of cesium–137 relative to potassium in going from one trophic level to a higher level (in this case from diet to man). This phenomenon has been discussed by Pendleton *et al.* (*7*), who postulate that the increase in ^{137}Cs/K ratio

[3] This value of daily potassium intake is somewhat higher than that of 3.0 ± 0.3 g/day found by other investigators, and may reflect actual differences in diet composition (*3, 4*).

is essentially the ratio of the biological half-time of cesium–137 to that of potassium in the animal in question. The diet ratio and *in vivo* ratio curves shown in figure 3 have similar shapes; however, the diet ratio reached a maximum approximately 4 months earlier than the *in vivo* ratio. The excursions in the values of the diet ratio seen during late 1961 and through most of 1962 are doubtless due to the presence of fresh cesium–137 coming into the food supply. This contamination may vary not only in time, but also in distribution throughout a given food item such as milk. In any event, the *in vivo* ratio does not clearly show these variations, but tends to smooth them out in the increasing trend of the ^{137}Cs/K ratio in man during this time.

In figure 4, the diet ratio data have been transformed to coincide, as far as possible, with the *in vivo* ratios. This transformation was accomplished by increasing the diet ratio by a factor of 3.0 and by moving the entire diet ratio curve forward in time by 4 months, so that the maximum would coincide with that of the *in vivo* ratio. This transformation results in a good fit between the diet and *in vivo* ratios from mid–1963 through mid–1965. The factor of 3.0 increase applied to the diet ratio is in accord with the hypothesis of Pendleton *et al.* (*7*), as regards the ratio of cesium–137 to potassium biological half-lives in man. A similar increase ratio was noted by McNeill and Trojan (*4*) during a limited time interval in 1959. Morgan and Arkell observed a threefold increase in the ^{137}Cs/K ratio between urine and whole-body measurements in early 1961 (*8*). The overestimation of the *in vivo* ratio by this transformation during much of 1962 and early 1963 is probably due in part to the nonhomogeneous contamination of the diet discussed earlier. It is also true that the transients in the diet ratio were of short duration, and equilibrium between diet and man was not possible under such circumstances.

Future values of the *in vivo* ^{137}Cs/K ratio may be found either from extrapolation of the transformed diet ratio or direct measurement of the *in vivo* ratio curves in figure 4. According to this approach, the *in vivo* ratio in the Chicago population should vary from 70 pCi ^{137}Cs/g K in early 1966 to 50 pCi ^{137}Cs/g K by the end of the year. At present the effective

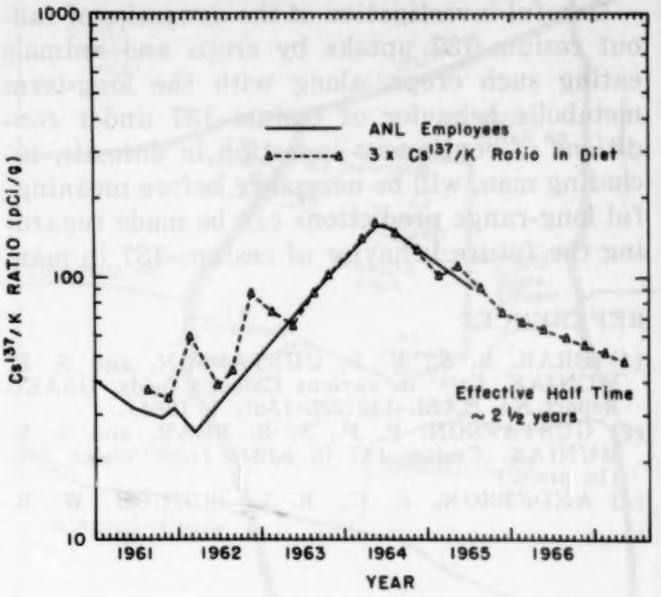

Figure 4. Comparison of human and modified dietary ^{137}Cs/K ratios

half-life of cesium–137 in human adults in this area—under conditions of continuous cesium–137 ingestion varying as indicated in figures 1 and 3—is 2½ years. The essential agreement at this time between these two sets of independent data places the prediction of cesium–137 body burdens over the next year or two on a rather firm foundation.

The ability to make longer range predictions, however, must await more precise knowledge in at least three areas: (1) the temporal changes in the cesium–137 content of the diet caused by storage or other delay mechanisms in the flow of foodstuffs from production to consumption; (2) the relative importance of accumulated cesium–137 deposition and fresh deposition after many years time; and (3) examination of the possibility that a portion of the total body cesium–137 burden is actually present in bone, and consequently may have a relatively long (>>100 days) biological half-time. This would cause the body burden to decrease more slowly than anticipated on the basis of diet information alone. Preliminary work done at this laboratory in 1961 indicated that as much as 10 percent of the total body cesium–137 might have resided in bone during 1961 prior to the resumption of nuclear tests (*9*).

Careful investigation of the dynamics of fallout cesium–137 uptake by crops and animals eating such crops, along with the long-term metabolic behavior of cesium–137 under conditions of continuous ingestion in animals, including man, will be necessary before meaningful long-range predictions can be made regarding the future behavior of cesium–137 in man.

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ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of the environmental radioactivity data for 22 AEC installations have appeared periodically in RHD since November 1960. Summaries follow for the Brookhaven National Laboratory and the Rocky Flats Plant.

Releases of radioactive materials from these installations for the periods covered in the reports below are governed by radiation protection standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1] These standards, which include radioactivity concentrations limits, are applicable to effluents released from AEC installations.

[1] Part 20, "Standards for Protection against Radiation," AEC Rules and Regulations, contains essentially the standards published in the "AEC Manual." The AEC Rules and Regulations are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, on a subscription basis at $3.50 for 3 years.

1. Brookhaven National Laboratory
January–June 1965

Associated Universities, Inc.
Upton, New York

The Brookhaven National Laboratory (BNL) operations may affect the environmental levels of radiation in three ways: (1) by discharge of coolant air from the graphite research reactor, (2) by radiation from an ecology forest gamma source, and (3) by the discharge of low-level radioactive liquid wastes into a small stream that forms one of the headwaters of the Peconic River (figure 1).

Area monitoring

The radioactivity in the discharge coolant air is almost entirely due to argon–41, a beta-gamma emitter. Because exposure to argon–41 is due to external gamma, the monitoring is performed by measuring the exposure rate in milliroentgens per week (mR/wk) rather than the concentration in air.

Late in 1961 a 10,000–curie cesium–137 gamma source was installed in the ecology forest about 800 meters equidistant from the north and east boundaries (*1*).

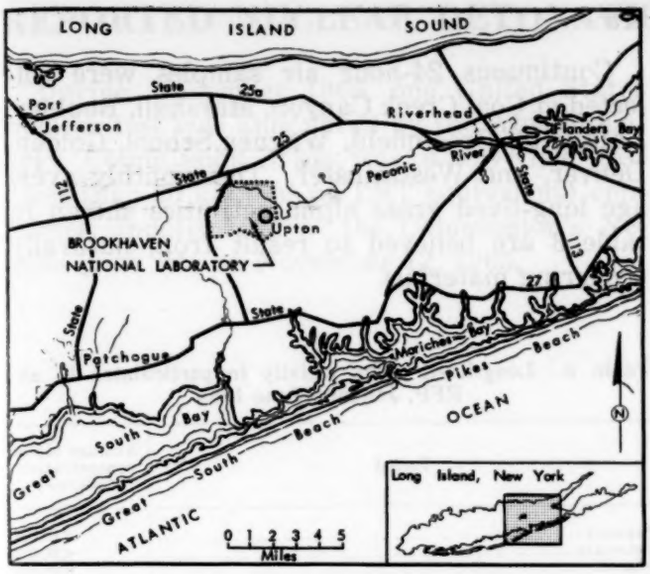

Figure 1. Brookhaven National Laboratory and surrounding area

Table 1 presents the average external gamma exposure rates measured at the four stations shown in figure 2. The higher levels of the Northeast perimeter station are primarily due to the ecology forest source. The environmental maximum permissible dose recommended by the Federal Radiation Council is 0.5 rem/yr (10 mrem/wk) above the natural background, averaged over a 1-year period.

Table 1. External gamma levels at BNL site boundary, January–June 1965

(Average exposure rates in mR/wk)

Period	Northwest perimeter	Southwest perimeter	Southeast perimeter	Northeast perimeter
Gamma exposure from laboratory operations:				
First half 1965	0.23	0.13	0.61	2.27
January	0.10	0.15	0.74	1.78
February	0.34	0.08	0.55	1.74
March	0.05	0.17	1.02	1.52
April	0.35	0.15	0.86	1.84
May	0.48	0.15	0.14	3.03
June	0.04	0.08	0.26	3.78
Average undisturbed background	2.10	2.11	2.45	2.35

Water monitoring

The BNL liquid waste effluent is monitored for gross beta concentrations at the site boundary. Table 2 presents the average concentration together with the total activity released as determined by using known effluent flow rates.

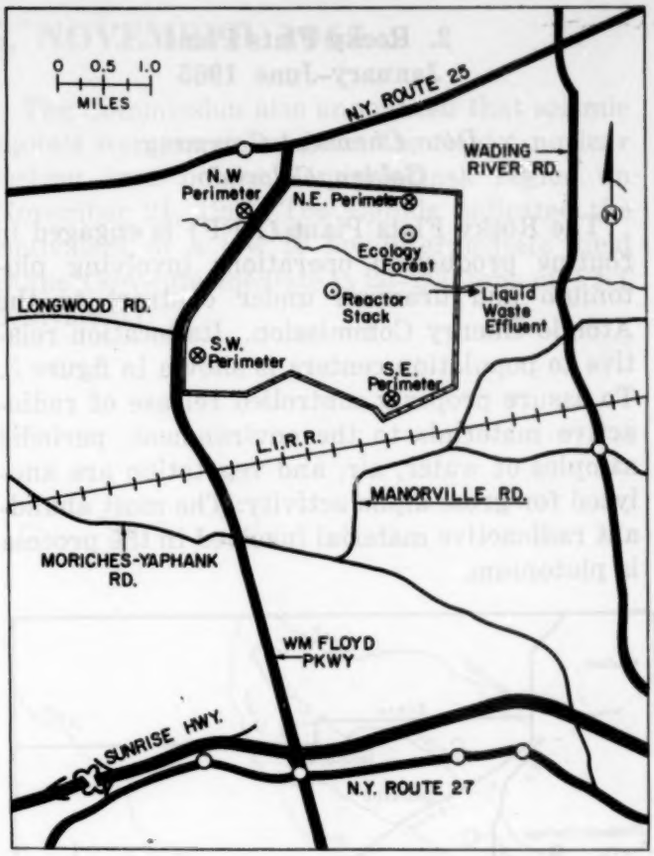

Figure 2. Brookhaven National Laboratory monitoring station locations

Table 2. Gross beta activity in BNL liquid waste effluent, January–June 1965

Period	Average beta concentration (pCi/liter)	Total beta activity discharged (mCi)
First half 1965	41	22.4
January	37	2.8
February	46	4.6
March	62	4.6
April	41	3.4
May	35	3.3
June	31	3.8

Recent coverage in *Radiological Health Data:*

Period	Issue
Third and fourth quarters 1961	*June 1962*
First and second quarters 1962	*January 1963*
July 1962 to June 1963	*February 1964*
July 1963 to June 1964	*December 1964*
July–December 1964	*June 1965*

2. Rocky Flats Plant
January–June 1965

Dow Chemical Company
Golden, Colorado

The Rocky Flats Plant (RFP) is engaged in routine production operations involving plutonium and uranium under contract to the Atomic Energy Commission. Its location relative to population centers is shown in figure 3. To assure properly controlled release of radioactive materials to the environment, periodic samples of water, air, and vegetation are analyzed for gross alpha activity. The most abundant radioactive material involved in the process is plutonium.

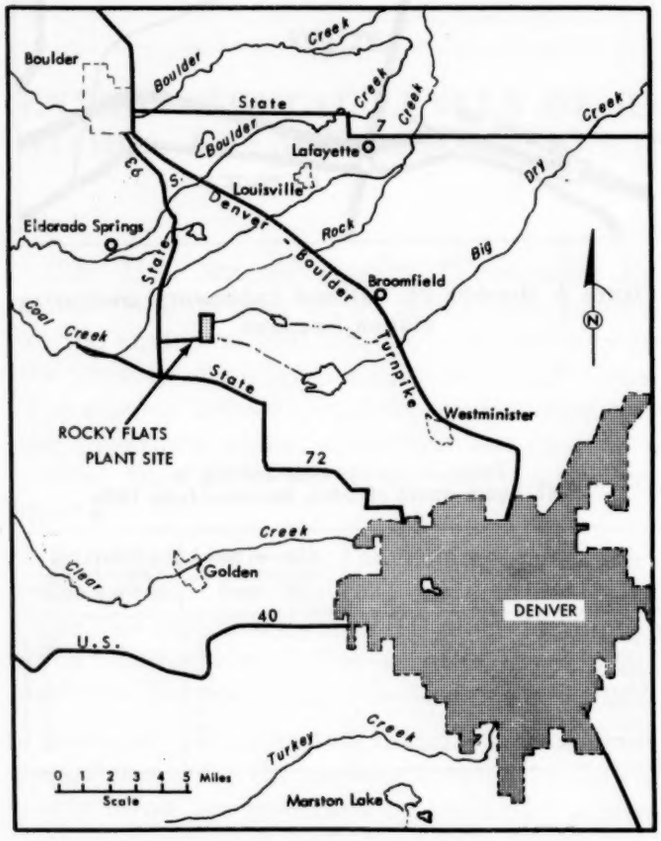

Figure 3. Location of the Rocky Flats Plant environment, Denver, Colorado

The plant is located about 15 miles northwest of Denver. The surface stratum in this area consists of gravel washed out of the highly mineralized Front Range of the Rocky Mountains, where heterogeneous low-level deposits of uranium, thorium, and radium exist in the soil. These materials are measurable in most samples of air, water, and vegetation.

Air

Continuous 24-hour air samples were collected at Coal Creek Canyon, Marshall, Boulder, Lafayette, Broomfield, Wagner School, Golden, Denver, and Westminster. The monthly average long-lived gross alpha activities shown in table 3 are believed to result from naturally occurring materials.

Table 3. Long-lived alpha activity in particulates in air, RFP, January–June 1965

Period	Average alpha concentration (pCi/m^3)
January	<0.006
February	<0.006
March	<0.006
April	<0.006
May	<0.006
June	<0.006

Water

Non-routine raw surface water samples were collected from a number of outlying streams and lakes along with the vegetation samples. Results of alpha activity analyses are given in table 4. Stream and vegetation samples will be reported later.

Table 4. Alpha activity in water collected from reservoirs in the vicinity of RFP, January–June, 1965

Reservoir	Average alpha activity (pCi/liter)
Great Western	2.1
Standley	2.5
Baseline	2.5
Ralston	2.2

Recent coverage in *Radiological Health Data:*

Period	Issue
July 1962–June 1963	*February 1964*
July 1963–June 1964	*December 1964*
July–December 1964	*June 1965*

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During November 1965, one United States nuclear test was announced by the Atomic Energy Commission. This was a low-yield test (less than 20 kilotons of TNT equivalent) conducted underground at the Commission's Nevada Test Site on November 12, 1965.

The Commission also announced that seismic signals were recorded from the Soviet nuclear testing area in the Semipalatinsk region on November 21, 1965. The signals indicated the equivalent of a low to low-intermediate yield range (low-intermediate is 20–200 tons of TNT equivalent).

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